

BRUMMAN

OPERATIONS PLANNING SIMULATION

MODEL STUDY

FINAL REPORT

REPORT NO. SU OPS-RP-74-0001

PREPARED FOR THE

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

CONTRACT NUMBER
NAS 8-30302

PREPARED BY
GRUMMAN AEROSPACE CORPORATION
BETHPAGE, L. I., NEW YORK

DATE: 23 May 1974

OPERATIONS PLANNING SIMULATION

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EXECUTIVE SUMMARY

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OPS MODEL STUDY

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1.0 OPS MODEL STUDY OBJECTIVES

Four primary objectives of this study were established by mutual agreement of the NASA/GAC study team at the "Study Orientation Meeting". These four objectives are defined in the following sections.

- 1.1 Describe and demonstrate the methodology used to quantify the resources required in terms of facilities, Ground Support Equipment and manpower.
- 1.2 Create time distributions for selected functions to be expressed as mean values modified by appropriate density distribution factors.
- 1.3 Investigation of the reasibility of automating modeling techniques to reduce the amount of time an analyst must spend examining the computer runs, thereby obtaining useful outputs in a shorter period of time.
- 1.4 Performance of a critique of an existing NASA simulation model in terms of programming, model utilization and output analysis.

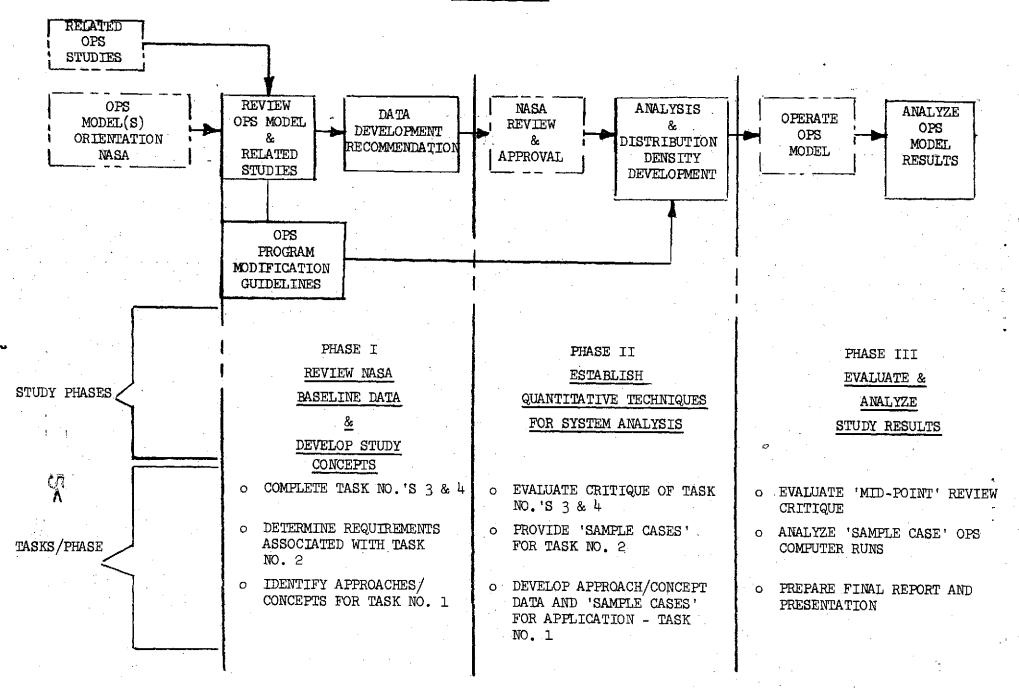
These four objectives are detailed in Appendices A through D of this report.

2.0 STUDY APPROACH

The Program was divided into three phases and the objectives within each phase were identified. Figure 1 shows the flow of these study functions. Those objectives identified in sections 1.3 and 1.4 were completed in phase I while the objectives stated in sections 1.1 and 1.2 were accomplished in Phases II and III.

The data and information generated in Phases I and II were applied to two Sample Cases to demonstrate the techniques involved in the application of this type of data.

STUDY PHASES



2.1 SAMPLE CASES

The methodology used in resource quantification was identical in analyzing both Sample Cases. In Sample Case No. 1, a top level block (Functional Level O) was taken from the NASA OPS model and expanded to Functional Level II. The block chosen was the function of integrating the Support Unit Simulator and the Experiment Module with Pallet. Tasks within this basic functional block were defined and waterfall time lines were developed.

From the task definitions, resources in terms of facilities, Ground Support Equipment and manpower were derived based on analysis and past experience. In assessing the manpower requirements, the factors affecting availability were involved.

The task times from the waterfall were used in an off-line simulation model which introduced randomness into these times to more realistically represent an actual operation; the result of this program were used in determing resource utilization.

For Sample Case No. 2, the Support Unit Simulator was excluded and the Sample Case examined the mating of the Support Unit itself with the Experiment Module/Pallet combination. The result of the attendant run indicated a reduction of elapsed time compared to Sample Case I.

3.0 CONCLUSIONS

In analyzing the objectives identified in paragraphs 1.1 and 1.2 study resources limited examination of more than the two Sample Cases stated; however, even in this analysis it becomes apparent that sensitivities will be apparent when applying the same methodology to the total functional flow, thereby becoming a valuable tool in early operational planning. Without the use of a simulation modeling technique,

3.0 <u>CONCLUSIONS</u> (continued)

the applications of time variations manually, becomes manpower consuming tasks with results that could come too late to allow effective management decisions.

It is, therefore, recommended that this technique be applied to all of the functional elements in the trunaround flow, tiering the time lines created to gain visibility into possible pitfalls in the flow.

The analysis performed in conjunction with the objective in paragraph 1.3 indicates that the automation of the simulation model, to the extent that the man is removed from the analysis loop is not efficient. A time sharing computer terminal, however, fulfills the needs of MSFC to even a far greater extent. The significant improvement in response time would more than offset the additional investment that would be required for this type of system.

In studying the objectives of paragraph 1.4 we fould NASA's simulation modes to be a fairly accurate representation of one alternative for the Shuttle Payload Ground Operating System. The model, however, still required further expansion and detail in certain critical points in the system. Consideration must also be given to the size of the model. The model must be held in check to prevent it from becoming too large and cumbersome to respond to active analysis.

OPERATIONS PLANNING SIMULATION

MODEL STUDY

APPENDICES

PREPARED FOR THE

GEORGE C. MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA

CONTRACT NUMBER

NAS 8-30302

PREPARED BY

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L.I., NEW YORK

DATE: 22 April 1974

OPERATIONS PLANNING SIMULATION MODEL STUDY

Introduction

With the advent of our next step in Space, the Space Transportation

System and its highly increased Launch rate, special tools must be

developed to permit rapid management decisions. Simulation modeling is such

a tool to be used for the identification of system sensitivities to internal

and external influences and variables. Further, it provides a means of

exploring alternate system procedures and processes, so that these alternates

may be considered on a mutually comparative basis permitting the selection of

a mode or modes of operation which have potential advantages to the system user

and operator.

These advantages are measurements of system efficiency; such as, the ability to meet specific schedules for operations, mission or mission readiness requirements, or performance standards and last but most significant to accomplish these objectives within cost effective limits. It is the prerogative of management to evaluate the data developed by the analyst through the simulation modeling technique and his interpretation of sensitive elements in the system, and to select the system alternate or alternates which should either further be studied or implemented.

Consequently, if the products of simulation modeling are to have significance, they must be in terms which are meaningful at management levels. Hence, terms which reflect mission performance parameters referenced to operational resource costs are necessary. If true cost data are not available but the outputs are in costable units, such as, square feet of facility space, or in skills and numbers of people for manpower, etc., then a comparative evaluation with realistic terms can be made. The purpose of the following guidelines, concepts, and technical data is to aid and assist the analyst in developing OPS model outputs which are more generally understood and interpreted.

Introduction (continued)

Four (4) study tasks were established by the mutual agreement of the NASA/GAC study team at the "Study Orientation Meeting" held on 2 and 3 October 1973, at Marshall Space Flight Center. The result of these tasks, described below, are included as Appendices A through D, respectively, in this final report.

Study Task No. 1 (Appendix A) was structured to define the methodology used to develop certain curves, tables, and matrices to quantify resources in terms of facilities, ground support equipment, and operational manpower. These guidelines, approaches, and technical data when applied to the OPS model analysis will effect the model so that outputs will furnish users with information of increased meaning.

The purpose of Task No. 2 (Appendix B) was to develop data which closely reflects "real-world" situations. The constant use of "Averages" or "Means" instead of random or varying processing "times" neglects an important consideration in the overall Shuttle payload ground operations system.

When all activities and tasks are accomplished in a precise amount of time, events can be scheduled with a great degree of certainty. As these processing "times" become less and less constant and start to vary, delays or blockages in the system start to occur. These delays can have an adverse effect on the ability to meet the launch schedule, and must be taken into account. This is normally done by expressing the processing "time" in terms of a Mean Value and a modifying density distribution function.

Study Task No. 3 (Appendix C) was to investigate the feasibility of automating modeling techniques for the purpose of determining capacities and quantities. This task attempts to reduce the amount of time an analyst must spend examining the computer runs, thus obtaining useful outputs in a shorter period of time than is currently being realized.

Introduction

(continued)

Study Task No. 4 (Appendix D) was to make NASA analysts at MSFC the beneficiary of GAC's many years of experience in the field of simulation modeling. GAC has some nine (9) years experience in developing computer simulation models for analysis and quantification of support resources (i.e. facilities, equipment, spares, personnel, etc.).

OPS MODEL STUDY

APPENDIX A

RECOMMENDATIONS FOR EFFECTING OPS MODEL OUTPUTS IN QUANTITATIVE TERMS FOR OPERATIONS RESOURCE REQUIREMENTS

REPORT NO. SU-OPS-RP-73-0002A

PREPARED FOR THE

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PREPARED BY

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., N. Y.

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OPS MODEL STUDY

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1.0 STUDY TASK

This task was structured to define the methodology used to quantify resource requirements needed in the Central Integration Facility (CIF) for the turnaround functions of the Support Unit, Experiment Module and the experiments.

2.0 GENERAL INFORMATION

2.1 DEPTH OF ANALYSIS

Off-line analysis to be effective must be carried to a depth greater than that represented by the simulation model flow diagram. Depending upon constraints and information desired this depth must be at least one (1) level deeper. For most applications a "cut" of more than one (1) level is required.

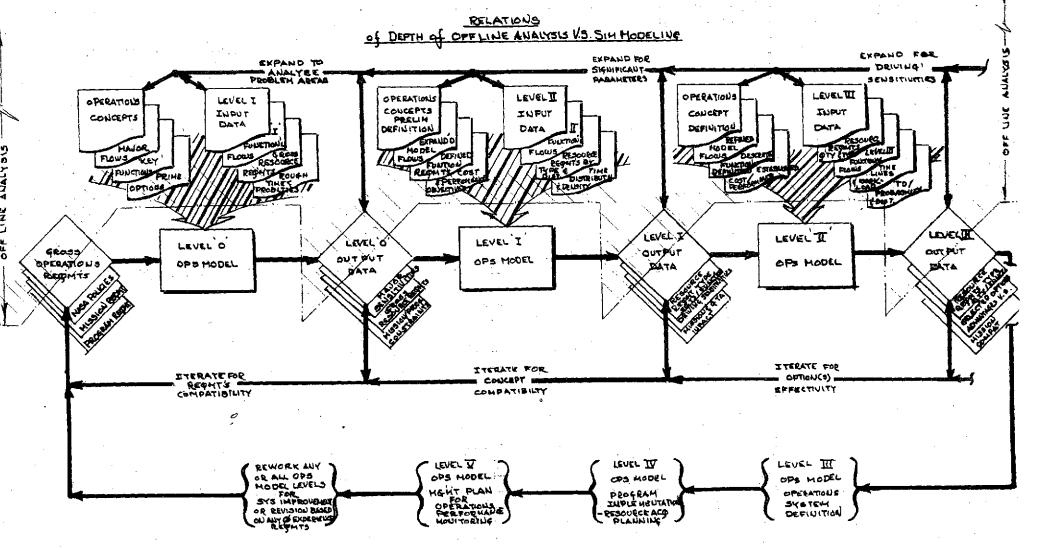
Figure No. 2-1, "OPS Model Evolution," shows the relationship between off-line analysis and simulation modeling for various levels of modeling studies. In addition, a brief description in diagram format show the level of detail of input data and output information.

2.1.1 Factors Affecting Depth of Analysis

The limits and requirements affecting the depth of analysis possible and required are:

- a) The level of intelligence and information available about the operational concept.
- b) The potential impact on system performance.
- c) The cost parameters of the operations option(s) under study.

FIGURE Nº 2-1 OPS MODEL EVOLUTION



OPS MODEL EVOLUTION

Fig Nº 2-1

6.1 [2.2] 1

2.1.1 Factors Affecting Depth of Analysis - (Continued)

Item (a) is the least containing element for initial study operations (levels 1 and 2) due to the fact that most systems can by hypothesized to a reasonable degree of validity. However, it is important that the ground rules used and the asseumptions made are clearly stated for the users consideration. In addition, the ground rules and assumptions should be updated to reflect the latest information as the concept matures and evolves.

Item (b) should result as a direct output of the model. Model flow paths and modes which generate queing effects in the process, require large amounts of resources, and affect schedules, mission readiness, etc generate requirements for greater depth of analysis and system exploration.

2.1.2 Cost Considerations

Item 2.1.1 (c) above, cost parametersm is the most important factor relative to the depth of analysis, due to fact that it is the most utilized criteria for judging system option advantages or disadvantages. The prime cost considerations involve two (2) major elements:

- a) Peak annual funding requirements
- b) Program life cycle costing

Both of the above are influenced by a further breakdown in cost elements and the overlap of the parts of this breakdown in program phasing. These are:

- c) Development cost
- d) Operational cost

The overlap of (c) and (d) above is a function of:

- e) Program major milestones
- f) Mission requirements

g) Procurement, requirement justification and development lead times.

2.1.3 Resource Requirements and Cost

Operations resource requirements which influence cost relationships are:

- o Fleet size number of flight articles
- o Site requirements number, location, and type
- o Facility requirements No., type, size, utilization
- o GSE quantity, type, utilization
- o Spares flight articles and GSE
- o Manpower Ops crew size and skills
- o Transportation & Handling inter & intra site ground turnaround
- o Training for unique skills acquisition and maintenance
- Publications technical data necessary for implementation of operations.

These resource elements are influenced by the functions in 2.1.2

(e), (f) & (g) and in turn influence the cost elements in (a),

(b), (c) & (d). The improvement of system effectiveness involves

trade-off studies between the functional elements (2.1.2 - e, f, & g),

their subsequent impact on resource requirements and the total

influence on cost parameters.

Table 2-1, "Operations Resource Commodities, Cost Considerations" show the major cost aspects for various resource commodities in diagram format. The relative values shown are referenced to the total program cost. In addition, average funding lead times are shown and general amortization periods indicated.

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RESOURCE	n	3 R&D	DAMUITH.	DACTUATION	Orgobia	OUAIU	@ opcoatu	12ATION
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FACILITY RESHIS	us/sme /functiv	() N	3-6	3	12-3			ំ10
G S E	SET/ FUNCTION	2-3	2-4	O	2-3		N/A/	10
SPARES	SET/FLT ARTICUE ORHADIE SET/SET G-SF	2	2-10		2-5	(A)	N/A	L
MAN POWER	#2000000 #250.p0\ #26.E00	(<u>)</u> o	0-		2	0-2	(Sp)	₽?
TRAUSPORTATION & HANDLING	HODE/ SITE MODE/ EUNCHA	3	34		() t	51 ² c-5	(3P) P	P
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PUBLICATIONS	SET / SKILL/ FUNCTION	3	$\left(\begin{array}{c} \\ \\ \\ \end{array}\right)$	D	000	0-5/	, vila	Þ
LRVELT LEGEND L-LIFE OF ITEM P-LENGTH (IU TIME) OF PROGRAM SP	~ VERY I COST ~ HIGH ~ SPECV	Cosr		ODERATE CHIVALCOS	οτ <u>()</u>	Relativ Lead T To Reg Except Which i Start	PECTS ARE VE TO TOTAL IMES REFERING MY JUSTIFIE TOUG ACTI STREFEREN DATE FOR O	CHICED CATION— UNITION CED TO PROPE

2.1.4 Model Flow Diagram

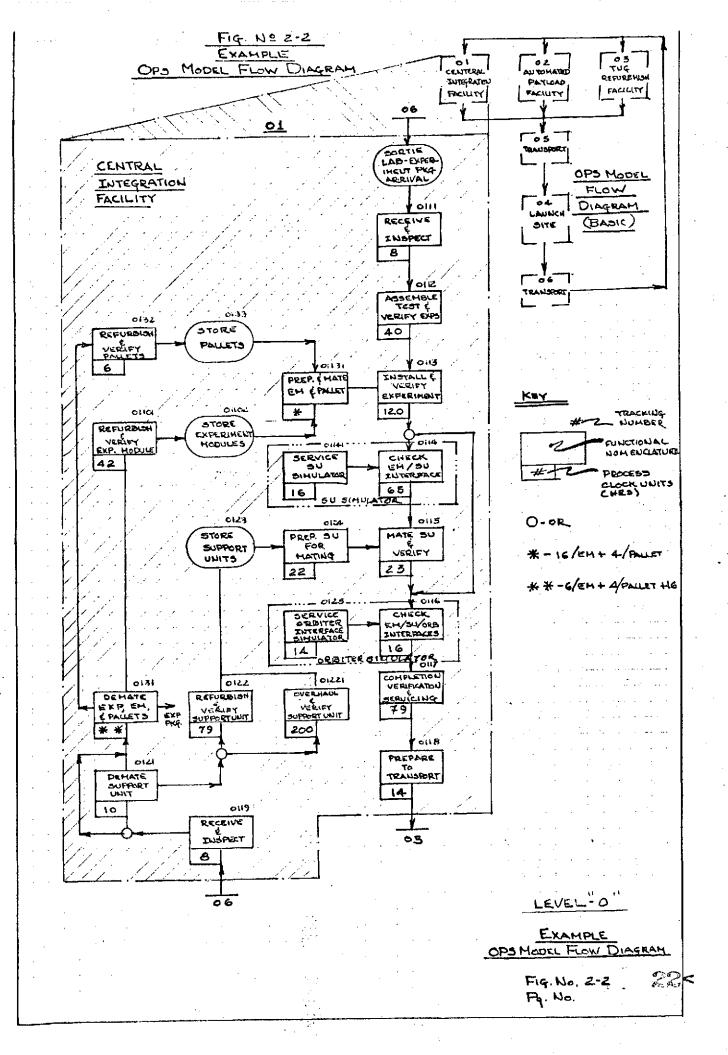
Figure No. 2-2 shows an example of the OPS Model flow diagram.

In the actual development of a flow diagram, logical segments of the system are first established through flowcharts. Starting with blocks which represent the major functions of the proposed system, more detailed logic is then introduced by adding blocks to depict more detailed operations.

After the overall logic of the system is established, certain segments are extracted from the general diagram and analyzed in greater depth. Proceeding in this manner, the block diagram becomes more detailed. The amount of detail depends upon the purpose and depth of analysis that is required. The goal is to produce a diagram which clearly shows all decision points in the system and which can be used to verify all possible conditions which arise during the operation of such a system (note that such a diagram is a model of the system).

Block diagrams provide the system analyst with a means of visualizing the sequence in which the logical and arithmetic operations take place within the system, as well as the relationship of one portion of the system to another.

It is usually desirable to keep the flow diagram as simple as possible consistent with system complexity and yet provide sufficient data so that the system can be understood. It is



more effective, if expansion of a portion of the flow is required for further investigation, to perform this as an "off line" effort and incorporate the output of this analysis as an input to determine the influence of that element on the remainder of the system. This procedure is further discussed in later sections of this report. See Sections 2.1.5 and 2.1.6.

2.1.5 Sel ion Criteria

Unless the study effort is to be very rigorously persued, there is usually little to be gained by exploring or expanding every facet of model. Hence, to be productive, the selection of model paths for further analytic treatment, such as functional flow analysis, time line development, etc., an ordering of priorities in analytic treatment is required. This ordering should allow the analyst to obtain the greatest amount of useful quantitative information for a specific level of analytic depth with the least amount of model complication. The priorities for selection include:

- a) Those paths or modes that involve the greatest number of the resources (see 2.1.3)
- b) Those paths, loops, and flows which generate process queing effects (see 2.1.1-b)
- c) Those parts of the model that involve the greatest number of elements in (a) above which may be considered "cost drivers" for the level of analysis in work or for the program phase under study.

2.1.6 Selection Application Procedures - "Off-Line" Analysis

There are no hard and fast rules for developing "off-line" analytic data. In any on-going model study, many efforts take place in parallel. As iterative analysis steps are performed and knowledge of the system sensitivities is acquired, certain "short-cut" steps become evident and some serial efforts can be deleted. Thus, in time "off-line" data and model outputs can be generated more effectively for selected applications.

While as mentioned, rules for application procedures are not hard and fast. (In fact a flexible approach offers the analyst some advantages depending on the response and type of data required). Certain basic steps seem to provide the best option for the generation of reasonable quantative data, (at least in the preliminary phases of analysis). These include the development of:

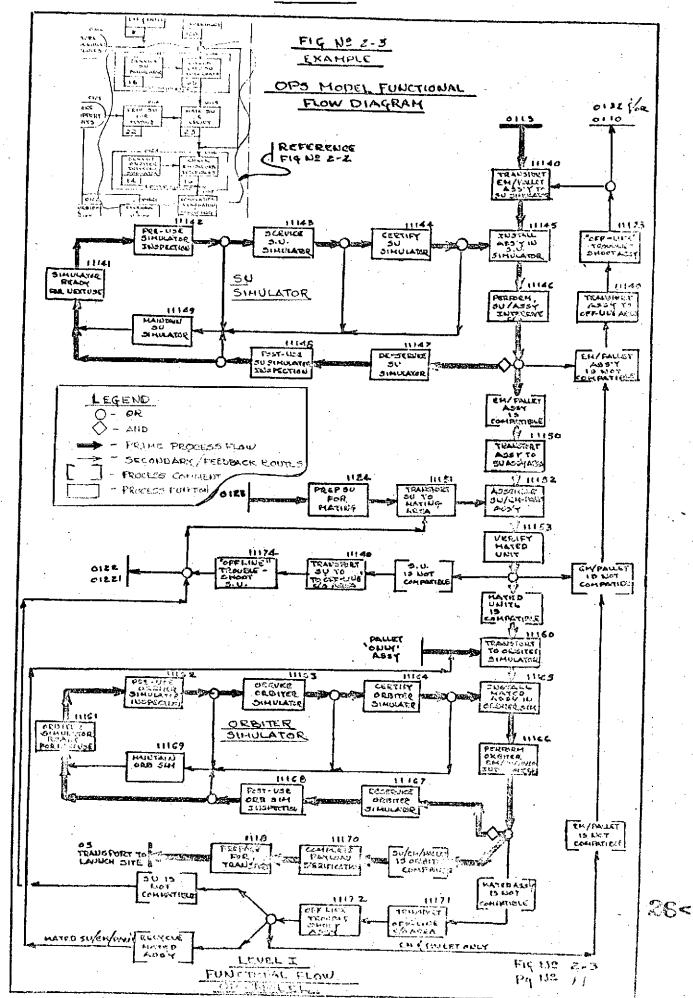
- o Functional flow diagrams.
- o Task scenarios (per major function)
- o Operational "time-lines"
- o Assign time distributions and probability parameters for selected functions (See Task No. 2, Report No. Su-OPS-73-0002B).
- o Resource allocation by function, event and/or activity.
- o Equipment, resource, and facility requirements data lists, tables, planning curves and criteria.

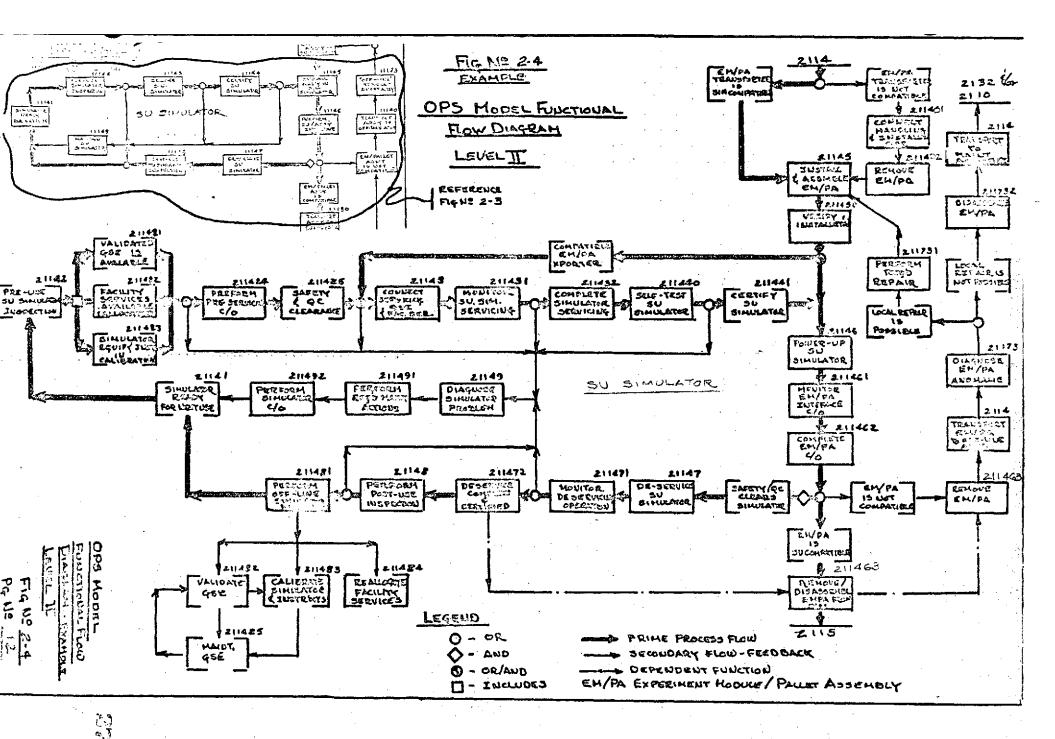
2.1.6.1 Functional Flow Diagrams

A function flow diagram is a pictorial representation of the steps, tasks and events involved in the accomplishment of a given process. Generally, the steps or blocks are arranged in the chronological order of occurence within the process under analysis. Sequential and parallel functions are shown and decision points highlighted.

Figure 2-2 shows an example of the OPS model flow diagram and while this is a pictorial model of the computer simulation model it is also a functional flow diagram of the payload (Central Integration Facility) processing system. If the model flow diagram is considered a "level O" diagram of the system, analytic processing of a greater depth is required to determine additional information about the system.

Figure 2-3 shows the diagram of the simulators (Support Unit & Orbiter) of one level of greater depth than the "level O" shown in the Fig.2-2, and additional decision points appear. Figure 2-4 is again an additional increase in the depth of analysis. This shows the functional flow to a level II for the support unit simulator. Again new flow paths are uncovered and additional system information is made clear. For this system additional levels of analysis will not yield much greater information about the system. Depending upon system complexity, the analyst is usually the best judge as to the number of levels (of depth of analysis) required to produce meaningful information about the system. In working the problem he can usually tell because of the knowledge gained in each step whether or not an additional





level will yield significant system information.

2.1.6.2 Interim Summary

At this point, a review of the material covered up to this part of the study is in order. Initially, ground rules governing the required depth of analysis to investigate system sensitivities and approach the quantification of resource requirements were presented. Next the influence of cost criteria and resource requirements were examined with the objective of identifying operations resource requirements which have a tendency to be system cost "drivers". The NASA/MSFC OPS Model was then evaluated and in an approach to develop "sample case" examples, the portion of the model dealing with the Central Integration Facility (CIF - Sortie Lab) was selected for further investigation. A Level I and II functional flow diagram was developed for the simulator section of the model since this part of the CIF flow closely satisfies the conditions stated in Section 2.1.5 "Selection Criteria".

The completion of the functional flow analysis to a suitable depth, (Level II in this case) provides a convenient break point for "off-line" analysis. Armed with the model flow diagram and the functional analysis, data specialists can commense investigations into, at the very least, gross operations resource requirements. The following portion of this report will present a sequential method of determining these requirements. However, if rapid response is required many of the following operations can be conducted in a parallel fashion.

2.1.6.3 Operational Task Scenarios

An initial step in the development processing time requirements and constraints is the generation of Task Scenarios for specific functions. In developing this data, a functional flow (in this case the SU Simulator Level II) is evaluated by identifying the operational tasks required to accomplish each established function in the flow, Table 2-4 shows an example of this type of data.

2.1.6.4 Operational Task - Time Allocations

Table 2-4 in addition to showing the Operational Task Scenarios, also shows process/task time allocations for each major function under the column marked "tot". In addition those processes which have variable processing times are indicated; such as, maintenance functions. The indicated time allocations were made to be consistent with the block times indicated in the Model flow diagram Figure No. 2-2. A latter phase of analysis requires an evaluation of these time allocations to determine whether or not these are realistic or must be modified to obtain "real world" results.

Table 2-4, also shows in the column marked "Pr" the probability of a change in process flow required by either a rejection of the flight hardware under test or a fault in the test equipment. Discussions in the Test Report No. 2 (SU OPSRP-73-0002B) will explane the application of time density functions and probability parameters to these functions as a typical application of this type of data in simulation modeling.

OPERATIONAL TASK SCENARIO

S.U. SIMULATOR

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FUNCTIO	ONAL FLOW	OPERATIONAL TASK	P _r
BLOCK NO.	NOMENCLATURE	<u>DESCRIPTION</u>	
211420	Pre-use Inspection S.U. Simulator	o Visual Inspection of Sim. o Remove all Dust Covers & protective packaging	A CARLO CARL
211421	Validated GSE is available	o Servicing GSE Functional set is ready i.e. "In Calib" & validated for next use	The California are a not
211422	Facility Services are abailable & allocated	o Proper Power & Pressures are available at sim. o Consumables have been allocated for next-use	0-5%
211423	Simulator Equip & Instruments are "In-Claibration"	o Check all instruments & equip for current Calib. certification	
211424	Perform pre-servicing check-out	o Perform limited sim. self-test - Gauge & instruments are functioning - Simulator is ready for servicing	The state of the s
211425	Safety & Q.C. Clearance	o Follow-up/Check pre-servicing. Conditions have been met	0-2/6
211430	Connect all ser vici ng GSE & Facility services	o Connect electrical cable assemblies o Connect all hoses & Flex tubing	
211431	Monitor S.U. simulator servicing	o Observe all servicing procedures o Record critical data i.e. rates, levels, flows, pressures, voltage, curreny, signals, etc.	0-107
	BLOCK NO. 211420 211421 211422 211423 211424 211425	211420 Pre-use Inspection S.U. Simulator 211421 Validated GSE is available 211422 Facility Services are abailable & allocated 211423 Simulator Equip & Instruments are "In-Claibration" 211424 Perform pre-servicing check-out 211425 Safety & Q.C. Clearance 211430 Connect all servicing GSE & Facility services	BLOCK NO. NOMENCLATURE DESCRIPTION 211420 Pre-use Inspection S.U. Simulator Validated GSE is available Validated GSE is available 211421 Pacific Services are abailable & allocated 211423 Simulator Equip & Consumables have been allocated for next use 211424 Perform pre-servicing check-out 211425 Safety & Q.C. Clearance 211430 Connect all servicing GSE & Facility services are available at sim. O Connect electrical cable assemblies on connect all servicing geservicing. Connect all hoses & Flex tubing 211431 Monitor S.U. simulator o Observe all servicing procedures o Record critical data i.e. rates, levels, flows, pressures, voltage, curreny,

Pr = Probability of REJECTION

% = TOTAL REJECTED

= FUNCTION REJECTED TO

OPERATIONAL TASK SCENARIO

SU SIMULATOR

tor	FUNCTIONAL FLOW		OPERATIONAL TASK	Pr
	BLOCK NO.	NOMENCLATURE	<u>DESCRIPTION</u>	
	211432	Complete Sim. servicing	o Top off all servicing functions o Complete servicing operations o Disconnect applicable GSE	
1.5	211440	Self Test SU Simul at or	o Run self-test procedure to determine readiness of serviced simulator for EM/PA interface C/O	.0-2%
	211441	Certify SU simulator	o Test Conductor/Authorized witness certifies Sim. is ready for EM/PA interface C/O	2.11490
	211401	Connect Handling & Installation GSE	o Connect lifting slings (EM/PA) and adapters o Schedule crane in place for load removal o Clear area	
	211402	Remove EM/PA	o Release EM/PA hold-downs on transporter o Take up on load o Lift out of transporter	The state of the s
9 hvs	211450	Install EM/PA & assemble in simulator	o Move Via crane adjacent to SU simulator o Remove protective coverings & dust covers o Lower in place in simulator o Align EM/PA in simulator o Lock-down assembly o Make-up all required connections.	0-1% 2.114m

OPERATIONAL TASK SCENARIO

SU SIMULATOR

}	**************************************	The state of the s	m the transport of the contract of the transport of the transport of the contract of the contr	de a same a same
tot	FUNCTION	AL FLOW	OPERATIONAL TASK	Pr
	BLOCK NO.	NOMENCLATURE	DESCRIPTION	dia se se se se se
3 hv	211450	(Optional-if EM/PA transporter is SU simulator compatible) Install EM/PA & assemble in simulator	o Move EM/PA transporter adjacent to sim. o Remove protective coverings & dust covers o Align transporter & assembly to simulator o Mount in place o Make-up all required connections	0-1% 211400 **
5 hrs	211460	Power-up SU simulator	o Open all required vent valves o Bring up elect. Pwr o Build-up required pressures o Commense initial signals for end-to-end SU/FM/PA check-out	7.
45 hrs	211461	Monitor EM/PA Interface C/O	o Observe all SU interface procedures o Record all critical interface data o Monitor test self protection Ckt's & devices	c-5/c Z11490
15	211462	Complete EM/PA SU interface C/O	o Complete all EM/PA interface procedures o Power-down simulator o Remove all pressures & safety all lines o Purge & Decontaminate all required lines, ducts, & surfaces o Evaluate Test & C/O Data	

OPERATIONAL TASK SCENARIO

S.U. SIMULATOR

tot	FUNCT	IONAL FLOW	OPERATIONAL TASK	P _r
	BLOCK NO.	NOMENCLATURE	<u>DESCRIPTION</u>	
3 hrs	211463	Remove EM/PA from SU simulator	o Disconnect all interfaces with SU simulator o Install all protective covers o Install handling & transportation GSE o Position overhead crane & install lifting sling o Lift EM/PA free of simulator o Transport via crane to transporter o Install in transporter o Connect all EM/PA o Disconnect all handling GSE	
i hr	211400	Transport EM/PA to off-line area (optional)	o Remove transporter from production flow area away from SU simulator	0-10%
1-16hr	211790	Diagnose EM/PA a nomalie (optional)	o With suitable GSE determine if local minor repair of non compatible EM/PA is possible o Evaluate data from off-line & SU simulator tests	
1 - 1 Ghv	211791	Perform required repair (optional)	o Perform local (minor) repair or adjustment o Inspect workmanship of repair action o Prep for re-installation SU simulator	2

OPERATIONAL TASK SCENARIO

S.U. SIMULATOR

t o+	FUNCTIONAL FLOW		OPERATIONAL TASK	P
	BLOCK NO.	NOMENCLATURE	DESCRIPTION	
ihr	211400	Transport to maint. facilities (optional)	o Transport EM &/or pallets to maintenance activities	
	211470	De-service SU simulator	o Preform all preliminary de-servicing procedures o Preform required safety inspections - Vents & purge lines clear - Required jury struts in place o Connect required GSE (functional set for de-servicing)	0-5/6
3.5 hrs	211471	Monitor de-servicing operation	o Observe de-service OPS o Record all critical data o Monitor protective CKTS and devices	211490
	211672	De-service complete & certify	o Complete de-service o Clean/de contaninate all lines o Power down simulator o Authorize test conductor/ witness certifies safe de- servicing de-serviced condition	

OPERATIONAL TASK SCENARIO

s.u. SIMULATOR

tot	FUNCTIO	NAL FLOW	OPERATIONAL TASK	Pr
	BLOCK NO.	<u>NOMENCLAUTURE</u>	<u>DESCRIPTION</u>	neart.
1.5 hr	211480	Perform post-use inspection	o Perform Su simulator post-use self test o Perform simulator off line C/O with portable test equip. o Do routine preventative maintenance o Install protective covers & packaging	0-2%
	211410	Simulator ready for next use	o Evaluate test & maint. data o Authorized personnel certifies readiness o Process control notified, simulator ready for next use	-
1-16hc	211490 S	Diagnose simulator problem	o Perform available self-test procedures o Perform off-line test checks	
8-40 hy	211491	Perform required maint. action	o Remove isolated fault or faulty component o Replace component/repair fault	
1-40h	211492	Perform simulator check-out	o Retest for fault correction o Perform all recertification test procedures o Certify simulator readiness for use	A.
·-v-	211481	Perform off-line simulator functions	o See below	1

TABLE NO. 2-4

OPERATIONAL TASK SCENARIO

S.U. SIMULATOR

tot	FUNCTIONAL FLOW		OPERATIONAL TASK	P.
	BLOCK NO.	NOMENCLATURE	DESCRIPTION	-
8 773	211482	Validate GSE (each use or pre- determined frequency)	o Perform GSE test to insure readiness for next use o GSE validation equip. calibration per determined frequency	Ēe Use
16 hrs	211485	Maintain GSE	o Perform test to isolate fault or bad component o Repair fault/replace component o Per form validated C/O 211482	IOJ Ez. 4 Uses
40 hrs	211483	Calibrate simulator equip. & instruments	o At given cycle time recalibrate inst's & equip. o Local calibration o Lab calibration	ises
8 hvs	211483	Re-allocate facility services	o Speciality power requirements pre process schedule o Determine rate of comsumables utilization o Allocate requirements for comsumables	Ea. Use
2 h vs **	211792	Disassemble EM/PA (optional if local repair is not possible ** ONLY IS OPTION 15 OFTICE	o Remove protective covers o Disassemble unit (can be done in off-line area or at the original ass'y point. o Disconnect all hard points & interfaces o Install in component transporters o Lock all component hold downs	-4-

2.2 QUANTIFICATION OF RESOURCE REQUIREMENTS

2.2.1 General Background

If Table 2-1 is perused, it can be readially be determined that the cost drivers in any aerospace system are:

- a) Fleet size number of flight articles
- b) Site requirements number, location and type
- c) Facility requirements No., type, size, utilization
- d) GSE quantity, type, utilization
- e) Spares for flight articles and GSE
- f) Manpower crew size and skills

Items (a) and (b) are usually fixed to some extend, at least in the initial system appraisals. Subsequent, analytic iterations usuall consist of comparing various operating modes and alterations of these items to optimize the system or to measure the influence of these variations on the quantities & cost of the remaining resources.

Item (e) is responsive to system parameters in somewhat a different manner than the other resources. Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and other maintainability factors cause pertubations in quantifing this resource requirements. The net result is that spares are usually considered in a separate off-line analysis. This can be done as a separate model so that the influence of alternate operations, changes in maintainability factors or other operations can be readilly acessed.

2.2.2 Resource Requirements - General

Resource requirements, particularly those listed in (c), (d), and (f) above (Sect. 2.2.1) behave in a non-linear fashion with respect to work load. Figure No. 2-5 below shows this relationship.

FIG. No. 2-5

RESOURCE IN \$ OR QUANTITY

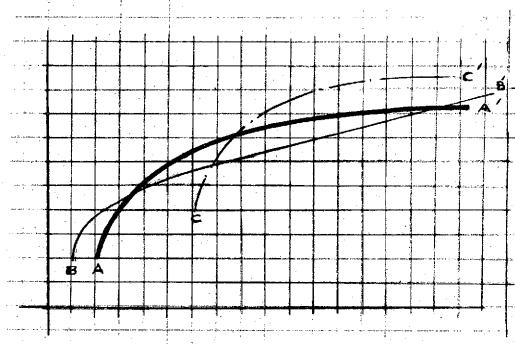
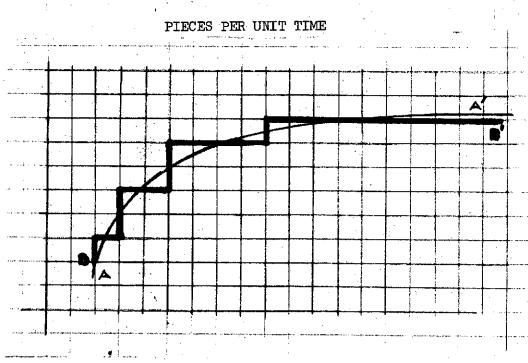


FIG. No. 2-5A

RESOURCE IN \$ OR QUANTITY



PIECES PER UNIT TIME

In general resource requirements expressed in quantative costable units increase with respect to the workload in a curve, conic in form, approximating 1/2 a parabola. The transverse axis is parallel to workload (the abseissa) and it and the vertex are displaced by amounts equivalent to "minimum" requirements associated with the function to be accomplished. Workload can be expressed in many ways; such as manhours, pieces per hour, units per calander unit, etc.

2.2.2.1 Factors Affecting Resource Requirement Curve Shape

In Fig. No. 2-5 curve A-A' respresents a typical aerospace workload/
resource requirements condition for refurbishment, maintenance and
reconfiguration. Curve B-B' shown in the same figure would be typical
of an infrequently performed or quasi custom type of operation.
After inital investment the requirements increased in somewhat a
linear fashion as the workload increases.

Curve C-C is more typical of a high production operation, in which initial investment requirements are high but the curve rapidly flattens out as workload increases.

respresents the actual growth in resource requiremnts in a stepped form with respect with workload. This is due to the fact that equipment, facilities and manpower permit certain limited growth in workload without corresponding increases in resource investment. However, as saturation of the growth potential occurs, small increase in workload can cause large increase in resource investment. Once the system definition begines to be firmed up, these "break-points" become important items for off-line analysis and investigation; since these

"break-points" and assoicated margins for resource utilization determine the operational constraints of the system for various modes of implementation. Curve A-A' in the same figure (Fig No. 2-5A) shows the average results of B-B'. The average type curve are advantageous in the initial steps of system definition and are also usefull in comparing different systems; particultary, when investigating the influence of workload on resource requirements for varios system configurations and options.

2.2.3 Resource Requirements - General Approach

Of significance in developing the proper curve to reflect the resource system condition with respect to workload, is the vertix displacement A B & C in Figure 2-5 in both the resourced & workload direction. displacement represents the minimum resource requirement to accomplish any useful work vice the amount of work produced by that resource or set of resources. The key in the preceeding statement is "Mimimum". Initial quantifications of resources per the functional flow blocks previously discussed in Section 2.1.6.1 and the Operational Task Scenarios, Section 2.1.6.3 must always be sized in the direction of the "minimum" requirement to accomplish the task or operational function under study. This, subsequently, establishes the "lower limit" for further analytic efforts which may require manipulation of the resource for increased or increasing workloads. A subset of this minimum requirement is the evaluation of each resource element to determine its utilization even though a certain set of resources is required to perform an operation, for instance, on a single payload element during a specified period of time the individual resource elements

may be under-loaded but necessary. This step helps to initially define the "break-points" discussed in paragraph (2) of Section 2.2.1.1.. Another subtility is, that when considering resource utilization vice elapsed time:

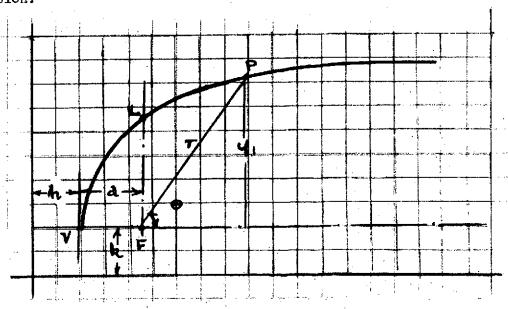
- o For Equipment & Facilities 69% = Full Load
- o For Manpower & Labor 89% = Full Load

The delta percent represent functional losses which must be considered such as: Equipment maintenance downtime, facility servicing, legitimate manpower lost time considerations, etc. These losses will be discussed in depth in subsequent sections of this report (see Section 2.3.6).

We have discussed various "off-line" analytic techniques in Section 2.1.6 and detailed examples will be given in Section 3.0. These are all directed toward to the definition of the "minimum" resource requirements for a given operational function. Figure 2-6 below may help explain the reason for attaching so much important to this concept of developing intially, a minimum resource set for a given function.

FIGURE 2-6

RESOURCE REQ'MTS IN \$ QUANTITY



In Fig. No. 2-6 above:

V = the vertix at "h" "k" = Min Resource Requirements (k) to produce (minimum useful) Workload (h)

The expression for this parabola is:

$$4a = (y - k)^2$$

$$(x - h)$$

The location of the focus (F) with reference to (r) is:

$$a = \frac{(y - k)^2}{4(x - h)}$$

The lattus rectum (LF) =
$$(y - k)^2$$

 $2(x - k)$

The location of any point (P) along the curve:

$$r = \underline{Y1} \notin \underline{e}$$
 where $e = 1$ for a parabola $1 \notin cos e$

Hence, in developing the parabola for resource requirements v.s. Workload, the expression for this curve is dependent on and in summertry with minumum resource requirements and useful workload output (h, k) by definition.

2.2.3.1 Significant Policies Affecting a General Approach

The development of certain policies will effect the sizeing of resource quantities associated with ground processing and maintenance refurbishment of payload modules and subsystems. Theses are the policies that result from the establishment of a philosophy for:

- o Test and Check-out
- o Level of Repair

There are many ways to approach the required philosophy associated with each of the above. However, most require significant definition of flight and ground systems prior to implementation. We will address here only those that apply during conceptual phases which consequently will require modification by more sophisticated methods as the program definition matures.

2.2.3.2 Test and Check-out Philosophy

It is essential that a test and check-out philosophy be developed if the resource requirements generated are to be realistic. As equipment definition improves very discrete test parametric can be addressed.

In the concept phase certain assumptions must be used. An ordering of priorities is necessary to establish this philosophy. These major considerations might be grouped:

- 1) Crew Safety
 - a) Flight
 - b) Ground
- 2) Safety Flight
 - a) Orbiter
 - b) Payload
- 3) Integration Requirements
 - a) Payload to Orbiter
 - b) Intra Payload
 - Spacelab Module
 - Automatic P/C & 3rd Stage
 - c) Experiments to Carrier

- 4) Mission Performance Requirements
 - a) Essentiality
 - National Security
 - National/International Significant
 - User/Customer Satisfaction
 - b) Total Manifest Readiness
 - c) Criteria for Success

For each potentinal site or sites an allocation of the above requirements must be made in order to evaluate resource requirements.

For the "Sample Cases" (See Section 3.0) examined in this study the following philosophy was applied. At the Central Integration Facility:

- a) All Spacelab parameters having a bearing on (1) crew safety and (2) safety of flight must be certified.
- b) Prime integration testing would concern primarily Spacelab

 Module(s) integration. Payload to Orbiter integration testing

 would involve essential physical fit and Orbiter interface

 continunity, with narrowly limited functional testing.
- c) Experiment testing will be limited to compatibility/interference checks and/or verification.
- d) Mission requirements testing will be limited Quick Reaction,

 Rescue and other limited payloads. Total manifest readiness will

 be determined by analysis of CTF, User, Primary Investigator(s)

 (PIs) and other test data.

All other testing will be the responsibility of other functional areas and sites. Another area of test and check-out involves the maintenance and refurbishment area. This is a specialized set of requirements and

requires additional allocation of responsibilities.

2.2.3.3 Level of Repair Philosophy:

This might also be called "Maintenance Concept". For defined systems, ther are sophisticated analytic methods of determining the cost effective Level of Repair (LOR). These are defined for military aircraft programs in MIL STD 1390 (Navy) and AFLCM/AFSCM 800-4 (Air Force). Basically the technique involves evaluating the acquisition cost of the component, the resource and operational cost of maintenance to determine decisions as to whether the item should be maintained and at what level is it most cost effective to do this activity.

In initial system concept analysis; since, much of the required data to perform an LOR type of analysis is unknown. It is necessary to establish certain "ground rules". If these rules are applied universally then analytic proceedures will provide in the simulation model an "apple-to-apple" comparisons, when considerering various modes for system implementation. In the "sample case" examination (Section 3.0) which follows. The following ground rule LOR or "Maintenance Concept" has been applied:

- a) No major maintenance is performed on the CIF payload processing/integration line.
- b) All CIF process-line maintenance while limited to off main-line activity is further limited to
 - Top level diagnosisis
 - Remove & replace actions
 - Align, adjust, recalibrate actions

- The Central Integration Facility will have adequate here
 I & II maintenance shop capability for the primary task
 of spacelab integration. Certain Level II shops may be
 located elsewhere; however, the processing of Level II
 maintenance work, regardless of location, will not degrade
 P/L processing time.
- d) AGE/GSE required for the support of the P/L integration process will be maintained, calibrated, refurbished, etc. in an off-line manner and will not affect the main line P/L processing time.
- e) Industrial or Militar/Industrial Level III (depot) maintenance requirements are recognized but not defined in this analysis.

 For the purpose of this study, this capability is assumed to be adequate to support the expected workload.
- f) Adequate spare parts will be available to support the CIF processing requirements
- g) Existing installation, facilities and capabilities will be used where ever possible.

2.2.4 <u>Facility Requirements - General Approach</u>

The lead time associated with the acquisition, design, construction or modification and the activation of facilities imposes in most aerospace systems a strong requirement for early definition. In addition, the high intital cost associate with this resource further imposes the requirement for rather rigorious analysis. The details associated with requirement are some evolutionary in that the level of detail associated with the requirement increases for various phases of the program. The detail evolution is as follows:

	Program Phase	Requriement Data	Purpose
a)	Concept Definition	Gross Functional needs	Trade studies - System Selection criteria
ъ)	System Definition	Refined Functional Requirements - Screen against existing assets	Scope total requirements - New Construction modification of existing structures
		Integrate requirements for maximum utilization	- Establish buget requirements
c)	System Implementation Program Definition	Scale drawings & models Detail definition of utility and facility service requirements	Furnish requirements to A & E design contractor Provide cognizant activities with timely activation
		Establish activation schedules consistant with program	data for effective implementation
a)	Operational Program	Review design data for requirements compatibility	Contract new construction &/or facility modification Install and verify equipment
		Develop GSE interface data for equipment installation	- Perform requirements demonstrations to assure System performance
		Review and evaluate construction progress	Implement operation

The present level of STS definition permits significant analysis primarily addressed to the first two categories above (a & b).

In order to assist in scoping facility requirements the data in Tabel 2-5 is presented. This data summarizes planning data used for scoping military aircraft requirements. While not directly applicable to the STS program it does furnish a comparative example of analogous facility requirements. This data was developed by Grumman during the NAFAC study for the Naval Facilities Engineering Center and was the result of in depth analysis and evaluations conducted at seven airstations having significantly differing mission requirements.

TABLE 2-5 (NAVY) AEROSPACE FACILITY REQUIREMENTS SUMMARY			
A/C Shop	Workload Manpower	Sq. Feet Required	Analogous to STS (Level II)
Power Plts	10 - 14 150 - 170	9,200 56,100	RCS System Rocket Eng.
Airframe	0 - 20 160 - 180	5,500 21,000	P/L Structure Mech. System
Avionics	0 - 50 160 - 180	20,000 64,500	Astrionics
Armament	0 - 2 39 - 48	4,500 10,500	Pyrc's, Pyro. System
GSE	0 - 10 66 - 70	3,050 21,200	GSE

2.2.4.1 Large Equipments and Installations

The requirements associated with large equipment, installations and assemblies are dictated by the size of these elements. In addition allowances must be made for the handling and installation of these. Such things as turning radius, hook heights, door clearance cannot be neglected. An example of this type of requirement is given in the "sample cases" discussed in Section 3.0 of this report. In the case examined, the S.U. simulator, the probable size of the simulator and the EM/Pallet assembly dictate the facility requirements.

Parameters which must be established for this type of a facility requirement include,

- o Area in square feet
- o Overhaul limits high bay requirements
- o Floor loading static and dynamic
- o Overhead Crane capacity & hook height
- o Cleaniness Requirements

Requirements for this type of facility at same point in evolution are enhanced by scale physical models to assure adequate consideration has been made for the associated handling and movement parameters.

2.2.4.2 Level III, Maintenance Shops

The depot shop requirements are perhaps the most difficult to quantify. The shops are similar to and sometimes identical with aerospace contractors industrial facilities. Rather rigorous studies must be made for these requirements to determine a cost effective approach. Whether it is more cost effective to maintain a production/refurbishment line at a contractors plant after the production phase is complete or should the Government establish a dedicated facility and capability to accomplish this function must be determined. The LOR discussed in 2.2.3.2 is an applicable technique for this type of an effort. Because this is such a specialized facility requirement it beyond the scope of this study to cover it any greater detail. However, such a requirement must eventuall be defined as part of the total STS program.

2.2.4.3 Level II, Maintenance Shops

These shops perform off-line maintenance and refurbishment of payload elements. They are usually located adjacent to the main processing line, but need not be located coincident with process (P/L integration)

line. The scope of work in this shops is limited to subsystem repair down to lowest shop replacement unit (SRU). These would include subsystem modules, and except in specialized cased, do not include component repair.

2.2.4.4 Mechanical/Structural, Level II Shops

These shops provide the capability to perform machine shop and sheet metal repair functions. Hence, equipment located in this type of a facility would include: lathes, drill press, millers, sheet metal brakes, welding booths, finishing equipment and x-ray, zyglow, magna-flux test equipment.

Parameter which must be identified to define this type of facility include:

- o Area in square feet
- o Floor Loading Static and dynamic
- o Overhead crane capacity & hook height
- o Electric Fower Voltages total connected load, phasing
- o Ventilation Requirements Welding finishing and x-ray inspection areas.

2.2.4.5 Pressures, Fluids & Cryogenic, Level II Shops

These shops are the location where maintenance is performed on hydraulic, ECLS, servo and cyrogenic sub-systems. The cryogenic requirement is the most expensive installation and is somewhat specialized and separated from the others depending on many factors. Such as the gases involved, required storage capacities, whether the gas is compressed at the site or delivered in cryogenic state. This requirement is a prime candidate for off-line analysis to generate

creditable information. The pressures and fluids type of shop usually has hydraulic test benches, pipe repair equipment, brazing units, and cleaning stations installed at the shop.

Requirements definition must include:

- o Area in square feet
- o Electric Power Voltage & connected load
- o Ventilation Requirements cleaning station
- o Safety Requirements safety cages, pressure vents, alarm systems
- o Cleaniness for servo & hydraulic pump repair stations
- o Lighting Lumen required at bench height for small assembly repair station.
- o Gasses & Fluids consumable storage or facility services
- o Drains To remove spills

2.2.4.6 Astrionic Shops, Level II

These shos are used to support electronic and electric subsystems. These include: communication, navigation and on-board automatic equipment. Floor loading in these shops are equivalent to light industrial loads.

Definition of requirements for these shops must include:

- o Area in square feet
- o Cleaniness for module repair areas
- o Electric Power Voltages, services (D.C., 60 & 400 Hz)

 connected load and regulation requirements.

- o Air Conditioning Requirements to maintain constant temp.

 and humidity
- o Lighting Lumen required at bench height
- o EMC/EMI grounding (power & instrument) Shielding if required

2.3 Ground Support Equipment - General Approach

In defining Ground Support Equipment at this stage of vehicle definition is done almost exclusively by comparison of existing or known vehicles having similar systems. Here, past experience on a wide variety of Aerospace vehicles is essential.

2.3.1 Functional Sets

The term Functional Set is used to describe all the items of equipment required to perform a given function rather than identifying individual bits and pieces that make up the set.

Having a functional set defined allows the visibility to look at total program and identify requirements when a given function is repeated in various parts of its life cycle.

2.3.2 Handling, Mechanical/Structural Equipment

As a general rule the least complex and lowest life cycle cost items of GSE, into this category falls slings, spreader bars, attach fittings access stands operational jigs and other items of this nature.

These items generally require little attention during their operational life.

2.3.3 <u>Transportation Equipment</u>

In this category we find items such as transporters covers and tie down kits. Although, for the most part, these items fall into the low-moderate cost range both for procurement and operations. However, in cases where services are demanded by the vehicle, such

as pressure and temperature maintenance environmental control to tight tolerances, this cost can become very significant.

For this reason, very early recognition should be made during vehicle design, and every effort made to eliminate requirements of this nature.

2.3.4 Pressure, Fluid & Cryo Equipment

Equipment in this group, with the exception of cryo equipment tend to fall in the high-moderate cost bracket for both procurement and operations, again however, the placing of unrealistic requirement on operational parameters can drive the cost for both procurement and operation "out of sight".

Cryo equipment, by its very nature is in the very high cost range both in initial procurement and its day by day operations. The key to cost reduction is making maximum use of commonality with all program elements.

2.3.5 Astrionic Equipment

The sophistication of present and planned space vehicles with the attendant desire for automation has driven this equipment to the very high cost for both acquisition and operations, with software costs approaching hardware costs in some instances.

The apparent method for cost reduction in this area would again be institutioning astrionic support equipment.

2.3.6 Manpower Requirements - General Approach

In this section we will define methodology to be used in establishing manpower requirements for the ground turnaround operations of the Spacelag. Also, ground rules and assumptions will be listed.

2.3.6.1 Minimum Crew Sizing

In establishing the crew required to perform the various tasks within the functions, the following ground rules will be applied.

- o Experiment peculiar requirements will not be included.
- o "On line" maintenance limited to remove and replace.
- o One man year equals 1848 man hours. This Manpower Conversion Factor (MCF) represents the following:
 - 80 hours vacation
 - ll paid holidays
 - 2 hours voting time
 - 40 hours sick/personal time
 - 22 hours misc.

This MCF will be used to size the crew based on traffic requirements.

2.3.6.2 <u>Influence of Learning and Effectiveness Factors</u>

Although primarily used in cost determination for recurring hardware production, the learning curve technique can be useful in predicting cost, in manhours, for any repetetive operation that is performed by a worker or groups of workers. Operations which are strictly machine functions obviously do not fall in this category.

Since the turnaround functions on the Space Lab are mainly repetetive in nature, we will apply the learning curve techniques in establishing the crew size.

Experience and past analyses have shown that operational learning closely follows at 90% curve to the 50% point, beyond this point, very little increase in operating efficiency is gained. The formula used for this time required is:

$$Tu = f[n^{1-x} - (n-1)^{1-x}]$$

where

Tu = time in manhours

f = first unit time

n = number of times function performed

x = 0.152 for 90% curve

There are other factors which influence manpower loading which we call effectiveness factors. These factors cost time, and must be accounted for. These "lost time" items include:

- o Coffee Breaks
- o Wait time (tool crib stock room, etc)
- o Equipment anomalies
- o Personal requirements

While these items seem to be quite obvious, they are often overlooked in early planning, resulting in repeated schedule "adjustments".

This lost time varies widely, depending on function, working conditions, and worker motivation.

In industry, the effectiveness factor for factory labor used in time and motion study is as follows: 'The standard time for a job will

be 130/100 of the amount of time nexessary to accomplish a unit of work, using a given method under given conditions, by a worker who possesses the sufficient skill to do the job properly ...'.

This industry factor is based on an average worker under average factory conditions. On the Space Lab we will assume a specially highly trained technician well motivated and working under excellent working conditions. Assuming all the above, and based on experience at both factory and field sites we will use an effectiveness factor of 111/100 for manpower determination.

2.3.6.3 Influence of Training Requirements on Manpower Planning

As a prerequisite to establishing a functional operational team aimed at the lowest operational cost in terms of manpower expended, we will assume a stringent training program for all skills and disciplines prior to first operational turnaround, this training will include both "classroom" training and on the job training.

Following this assumption, and recognizing that the Space Lab Program will require operational turnaround functions be performed on a relatively steady and frequent basis, it is felt that training refresher courses will not be required, skills will be retained by doing. Also it may be noted that attrition rate on programs of this nature is extremely low (less than 1% during active IM operations) so that training of new employees can be absorbed with no significant impact.

3.0 SAMPLE CASES

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In order to best demonstrate the techniques involved in quantifying resource requirements, examples based on the existing OPS Model were selected. Further, available study resource would not permit examination of every significant function. These examples are termed Sample Cases.

3.1 SAMPLE CASE NO. 1

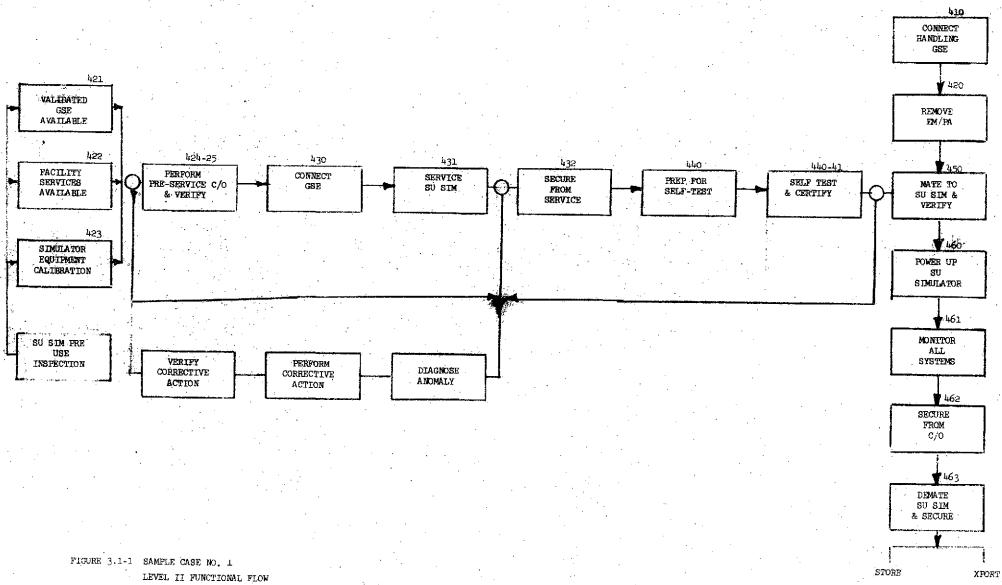
The example we will explore in this Sample Case involves those functions concerned with the checkout between the Support Unit Simulator and the EM/PA. The interfaces, as defined in the MSFC Simulator Requirements Document of 10 October 1973 include:

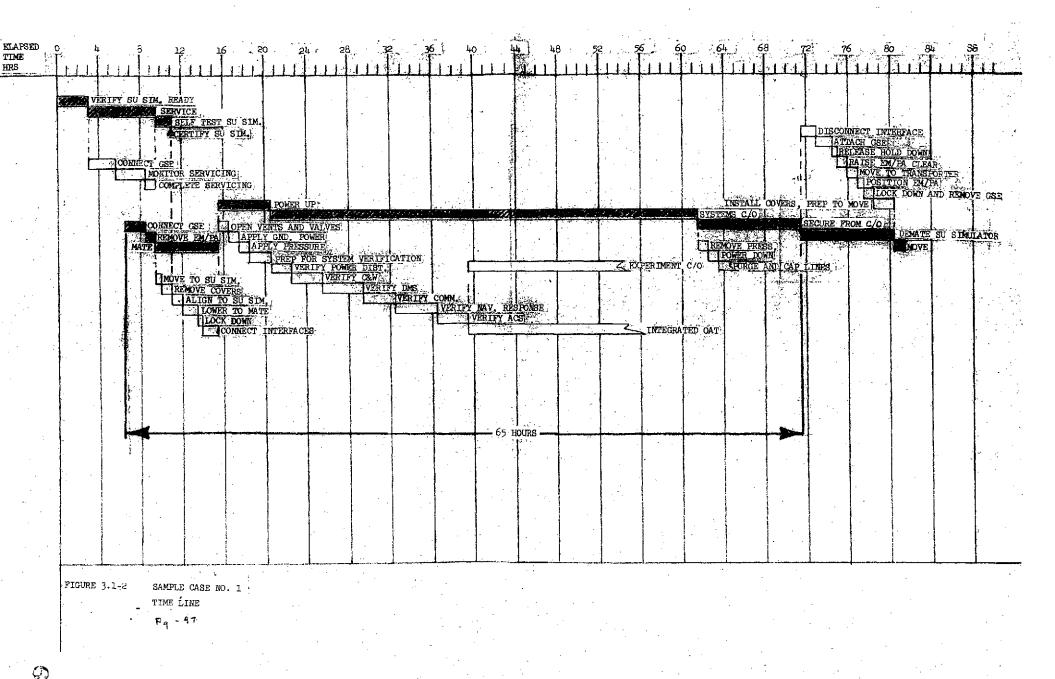
- Mechanical attachment
- Power distribution
- Data management
- Caution and warning
- Altitude control
- Navigation
- Communication

Those functions to be supplied by Ground Support Equipment are power, thermal and environmental control.

3.1.1 Functional Flow and Task Narrative

Figure 3.1-1 depicts the Level II Functional Flow we will use in this example. We assume, for this Sample Case that the EM/PA stand is not compatible with the SU simulator mating fixture.





The associated time line, Figure 3.1-2 was created using the Level 0 times from the OPS model, distribution to Level II was made to create the sub-flow within the basic function.

In order to accurately compare Sample Case No. 1 with Sample Case No. 2 in the following section, we will begin the Task Narrative six and a half hours into the time line flow.

The first task is to attach the lifting and handling GSE to the mated EM/PA; the hoisting sling will be attached to an overhead crane through the auxiliary crane control; slack taken up by the crane and TBD pounds applied using the aux. crane control. The EM/PA will be disconnected from its tand and moved to the SU simulator mating position. In parallel with this activity the SU simulator will be certified ready.

With the EM/PA in position, all covers, plugs and caps, will be removed. The EM/PA will be aligned with the SU simulator, lowered to mate and hard mated. All interfaces required for combined systems verification will be made, these interfaces will include hook-up to the required GSE.

Power up procedures are then instituted along with the ground equipment supplied thermal and environmental control. The integrated SU sim/EM/PA is prepared for system verification checkout sequentially followed by an integrated "Overall Test". During the OAT, experiments will be powered up to verify compatibility between all elements.

Upon successful verification of the integrated systems, pressurer and power are removed, lines and ducts are surged and capped.

Mean time, as shown in Figure 3.1-2, to accomplish these functions, is 65 hours. The off-line simulation of these functions (see Task 2) which introduces time variables, indicates that actual elapsed time may run from 65 to 77 hours, or an increase of 18.4%.

It must be noted that an amololy may occur at any point in the flow which could require diagnosis and corrective action increasing the flow time dramatically. This diagnosis and repair loop can easily be introduced to the referenced off-line routine.

3.1.2 SU Simulator Resource Breakout

In establishing resource requirements for the functions in Sample Case No. 1 two items are of particular significance. The first item, traffic date build must either be geared to the earning curve addressed in Sect. 2.3.6.2, or a penalty in early excess manpower will be incurred. If we examine the unit time formula $Tu = f(n^{1-x} - (n-1)^{1-x})$ and use 100 for n, solving for f or first unit time $f = \frac{1}{n^{1-x}}$

Tu we find that $f = \frac{Tu}{.5}$ or the first unit will take (100.848 - 99.848)

twice as long to process, in manhours then the 100th unit. Therefore, to perform the function either time or manpower must be adjusted.

The second item, maximum traffic rate impacts all resources if such rate requires parallel action on two or more vehicles. It can easily be seen that such parallel operations could result in additional facilities, manpower and GSE.

Therefore the following assumption has been made:

- a) Traffic at the CIF will never exceed 20 vehicles each year
- b) These 20 flights will be evenly spaced in a given year.

3.1.2.1 Functional Sets, Sample Case No. 1

Referring to the time line, Figure 3.1-2 the first task, that of positioning the EM/PA and mating the SU simulator requires the following: (1) Transporter Functional Set consisting of the EM/PA Transporter frame, mobilizer and associated covers. (2) Handling Functional Set consisting of slings, spreader bars and hydroset. (3) Alignment Fixture Functional Set consisting of gages and sights to properly align the EM/PA and the SU Simulator. These functional sets will be utilized for nine elapsed hours.

The second set of functions on the time line involves preparing

for and executing an Over All Test (OAT) of the mated SU simulator; the functional sets required are: (4) Ground Power Functional Set consisting of ground power supply controls and interfacing cables.

(5) Checkout Station Functional Set consisting of an RF front end and formatter, mini computer, modular CRT displays up link command module and all associated cables and antenna hats (6) Heat Transfer System Functional Set consisting of coolant storage tanks, refrigeration unit, trim control unit and associated lines and hoses. (7) Life Support Unit, Functional Set consisting of GO₂/GN₂ source, air conditioning unit, flow control panel and associated lines and ducts. (8) Access Functional Set consisting of various stands and steps enabling access to the mated vehicles. (9) Experiment Peculiar Functional Set consisting of any peculiar equipment required

for experiments. Under certain conditions one additional set may be required. (10) Zero "G" Simulator Functional Set consisting of a support frame cables, pulleys, counter-balances and springs to simulate a zero "G" condition for certain space moving experiments. These functional sets will be utilized for fifty eight and one-half elapsed hours.

3.1.2.2 Facility Requirement Sample Case No. 1

In assessing the facility requirements of Sample Case No.1, it was determined we would require an open bay of 4000 square feet in area, equipt as follows 35 ton crane, hook height of 35 feet, air conditioned, filtered air to maintain a 1,000,000 cleanliness level, shop air regulated and GN₂, 20V, 220/440V 60Hz service. Sized in this manner the space would support EM/PA placement and SU simulator mating. Utilization of this facility for Sample Case No.1 would be sixty-five elapsed hours per unit flow.

3.1.2.3 Manpower Requirements Sample Case No. 1

The Ground Operations Engineering Analysis (GOEA) method of detailed examination of each action which must be made to accomplish a given function is employed in determining the direct technician requirement needed to perform these actions. This analysis there, includes all of the elements of the function being examined. Once this direct labor is identified, percentages are used, based on past experience, to determine other supporting manpower. This support includes engineering administration, production control and publications.

Again entering the time line Figure 3.1-2 the function of moving the EM/PA to the mate position was examined and yielded the following:

DIRECT	SUPPORT	
4 Mech./Struct Tech	1 Crane Oper.	
1 QC	1 Mech. Eng.	
1 Safety		

Elapsed time is 4.5 hours (36 manhours)

For interface hook up we will add:

DIRECT

DIRECT

- 2 Avionic Techs
- 2 Fluid and gas Techs
- 1 Additional QC

Elapsed time is 1.5 hours (19.5 manhours)

The next function, that of prepping and running the mated SU simulator OAT was next examined and the following crew was defined:

SUPPORT

· · · · · · · · · · · · · · · · · · ·	
2 Mech/Struct Techs	3 Avionic Eng.
4 Fluid and Gas Techs	2 Fluids and Gas Eng.
5 Avionic Techs	
2 Q C	
1 Safety	
Elapsed time, including secure f	rom C/O equals 58.5 hours
(1111.5 manhours)	

Since the flow used in the sample case was entirely sequential, no parallel operation, we can define a single crew for the functions examined.

DIRECT	SUPPORT
4 Mech/Struct Techs	1 Mech Eng.
4 Fluid and Gas Techs	3 Avionic Eng.
5 Avionic Techs	2 Fluids and Gas Eng.
2 QC	1 Crane Op.
1 Safety	

Total elapsed time 65 hours (1167 manhours)

Taking the effectiveness factor from Section 2.3.6.2, however, indicates the actual time will increase to 1295 manhours (1.11 \times 1167).

These manhours, arrived at by simple mathmatics are now played against the simulation run from Task 2 which applies a time distribution function. From this run, we find that the average elapsed time is not the 65 hours of mean time initially used, but 77 hours. This increase of elapsed hours gives us an additional factor further increasing our expended manpower to 1.18 x 1295 or 1528 manhours expended for each turnaround.

Using the 10 flight maximum through the CIF shows that a total of 30,560 manhours will be expended to process these 20 units through the functional block examined in this Sample Case. With the basic crew we have available 42,504 manhours.

In this Sample Case, it was assumed that the mean times used represented a mature flow, if we now back up the learning curve to the first year of operation, and assume the same 20 flight rate, we find that the expended manhours increased to 54,379 manhours thereby exceeding our basic curve capacity. Figure 3.1-3 graphically portrays this increase.

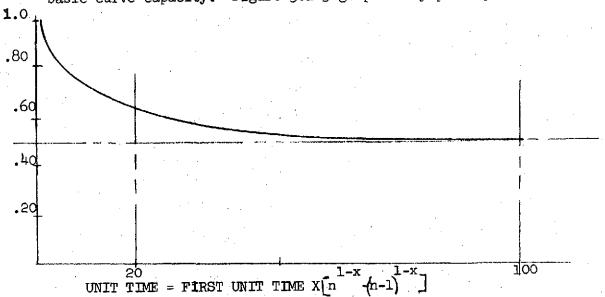
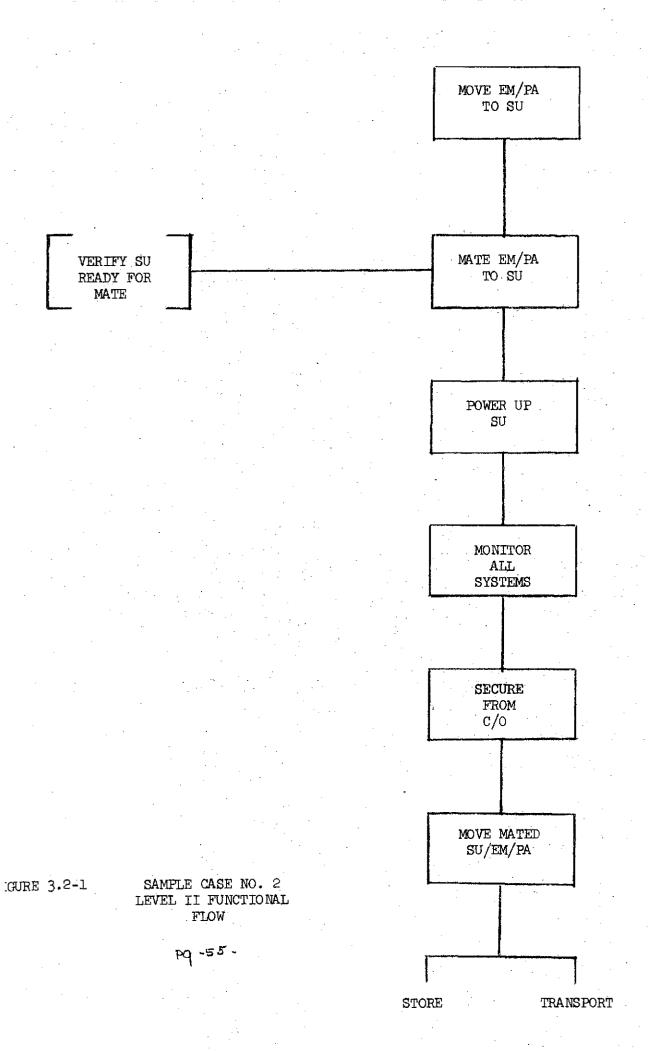


FIGURE 3.1-3

3.2 SAMPLE CASE NO. 2

In this example, we will explore those functions involved in the mating and checkout of the Support Unit itself with the EM/PA. The interfaces noted on Section 3.1 are the same. We will assume G.S.E. will provide the ground power, therman and environmental control. The thermal and environmental controls and distribution will, however, be through the flight system.



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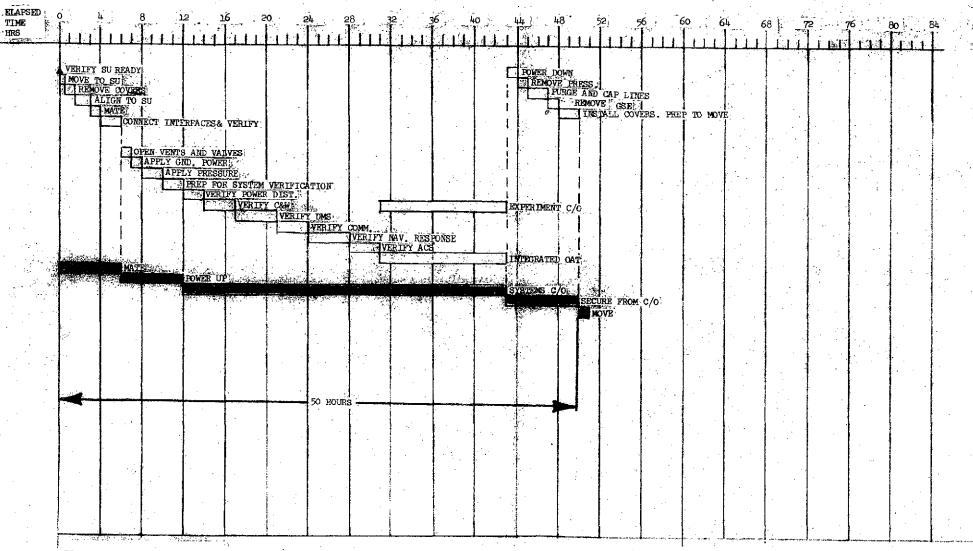


FIGURE 3.2-2 SAMPLE CASE NO.2
TIME LINE

Pa -56

3.2.1 Functional Flow and Task Narrative

Figure 3.2-1 depicts the Level II Functional Flow to be used in this example. In this Sample Case, we have assumed that the EM/PA stand/transport, is compatible with the SU mating fixture. Figure 3.2-2, the associated time line was generated by examining the activities required and assessing the time past on past experience with similar systems.

The first task in this ample is moving the EM/PA to the SU mating stand, it is assumed that the EM/PA stand/transporter is capable of being towed into position so no slings are required. When in position, all covers, plugs and caps will be removed, the EM/PA will be aligned with the SU and all interfaces will be connected.

Power up procedures are identical to Sample Case No. 1 as is the OAT. One additional function will be performed, that being a leak check between the SU and the EM/PA.

Following the secure from C/O, the mated SU/EM/PA will be prep to ship or enter a ready for issue storage.

As with Sample Case No. 1 anomalies may occur at any point in the flow resulting in down time for diagnoses and repair.

3.2.2 SU Resource Breakout

Resource requirements for the functions in Sample Case No. 2 are subject to the same problems noted in Section 3.1.2. The same assumptions will be made.

3.2.2.1 Functional Sets, Sample Case No. 2

The functional sets for Sample Case No. 2 are the same as those listed in Section 3.1.2.1 with two exceptions. These exceptions are 1) no handling functional set is required and 2) added to that equipment used in the OAT; (11) Cabin Leak Detector Functional Set consisting of a leak detection system and associated ducts and hoses.

3.2.2.2 Facility Requirement Sample Case No. 2 Same as Sample Case No. 1.

3.2.2.3 Manpower Requirements Sample Case No. 2

The same methodology used in Section 3.1.2.3 has been applied to this sample with the following crews defined:

Moving EM/PA to mating position

DIRECT	SUPPORT
3 Mech/Struct. Techs	l Tug O per.
1 QC	1 Mech Eng.
1 Safety	
Elapsed time 4 hours	(28 manhours)

APPENDIX A

For interface hook up we will add:

DIRECT

SUPPORT

2 Avionics Techs

1 Fluids & Gas Eng.

- 3 Fluid and Gas Techs
- 1 QC

Elapsed time 2 hours

(26 manhours)

For the functions for prepping for and running the OAT the following personnel are required:

DIRECT

SUPPORT

2 Mech/Struct Techs

3 Avionic Eng

5 Fluid and Gas Techs

3 Fluid and Gas Eng.

- 5 Avionics Techs
- 3 QC
- 1 Safety

Elapsed time, including secure from C/O equals 44 hours.

(968 manhours)

As with Sample Case No. 1, we can now define our basic crew:

DIRECT

SUPPORT

3 Mech/Struct Techs

1 Mech Eng.

5 Fluid and Gas Techs

3 Avionic Eng.

5 Avionic Techs

3 Fluid and Gas Eng.

3 QC

1 Tug Operator

1 Safety

Total elapsed time 50 hours (1022 manhours)

APPENDIX A

Again, from Section 2.3.6.2 the effectiveness factor increases the manpower expenditure to $(1022) \times (1.11) 1134$ manhours.

From Task 2, we find that the mean time, using the time distribution functions becomes 55 hours of elapsed time, or a 10% increase.

Utilizing this factor our actual expenditure becomes (1134) (1.10)

1247 manhours for each turnaround. For the 20/year turnaround of this mature flow, we will expend 24, 940 manhours out of an available 46,200 manhours.

Backing up the learning curve, as in Sample Case No. 1, we find that to accomplish 20 cycles in the first year, we would expend 37,862 manhours which is within our available manpower resource.

3.3 COMMENTS AND RECOMMENDATIONS

While examining the functions in Sample Case No. 1, and maintaining the concept of a Central Integration Facility, it was difficult to understand any real operational gains to be made utilizing an extremely expensive and complicated simulator for pre-SU mate verification. With the present limited visibility, we would recommend deletion of this simulator from the CIF flow. Upon additional study, this recommendation could change.

It is further recommended that waterfall time lines be developed and tiered to visually spot possible pitfalls in the flow. Also, off-line simulations, with built-in time variations should be developed for all critical functions.

OPS MODEL STUDY

APPENDIX B

CREATION OF TIME DISTRIBUTIONS

REPORT NO. SU OPS-RP-73-0002B

PREPARED FOR THE

GEORGE C. MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA

CONTRACT NUMBER

NAS 8-30302

PREPARED BY

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., N. Y.

OPS MODEL STUDY

APPENDIX B

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4.0	CONCLUSIONS	8

APPENDIX B

1.0 STUDY TASK

In this task, time distributions are created and expressed as mean values, then times are then modified by appropriate density distribution functions to more accurately reflect a "real world" situation.

2.0 INTRODUCTION

In the course of developing the Shuttle payload ground operations simulation model, NASA has introduced into the computer program processing "times" for various ground operations and activities. These "times" for the most part are "first-cut" estimates based upon NASA's past experience. They must still be refined to the point where normal expected variations in the operations and activities are considered.

This refinement of processing "times" will consist in a detail examination of the activity to be performed and breaking down the overall operation into more discrete, easily quantified tasks. Task "times" for these simple more basic tasks will be developed along with the possible variation in time that would normally be expected to occur. These "times" are then modified by appropriate probability distribution functions.

APPENDIX B

3.0 DISCUSSION

The detailed Level II flow for the SU simulation process, developed in Task - 1 SAMPLE CASE 1 was further expanded in this task to include probability distribution functions. An off-line, level - 2 GPSS simulation model was developed in order to evaluate this specific activity. Three basic probability distribution functions were used in the model to modify the specified mean values (fig. 1).

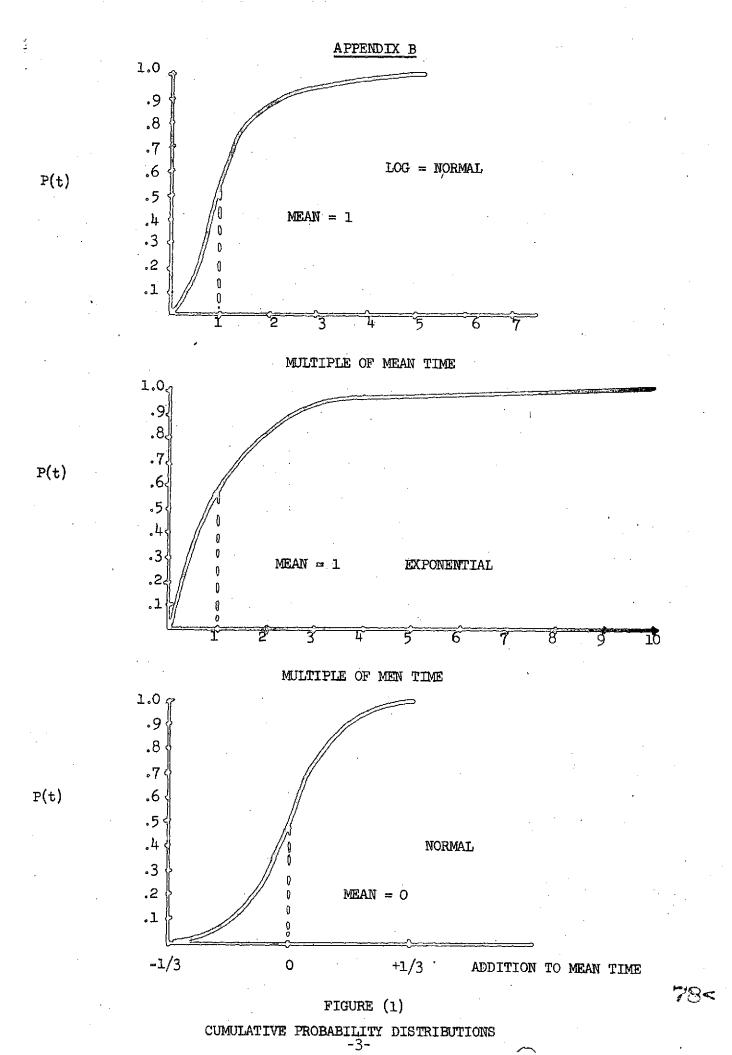
The log-normal distribution, with a mean value of one (1) was chosen to modify those activities which consisted of basically a repair function.

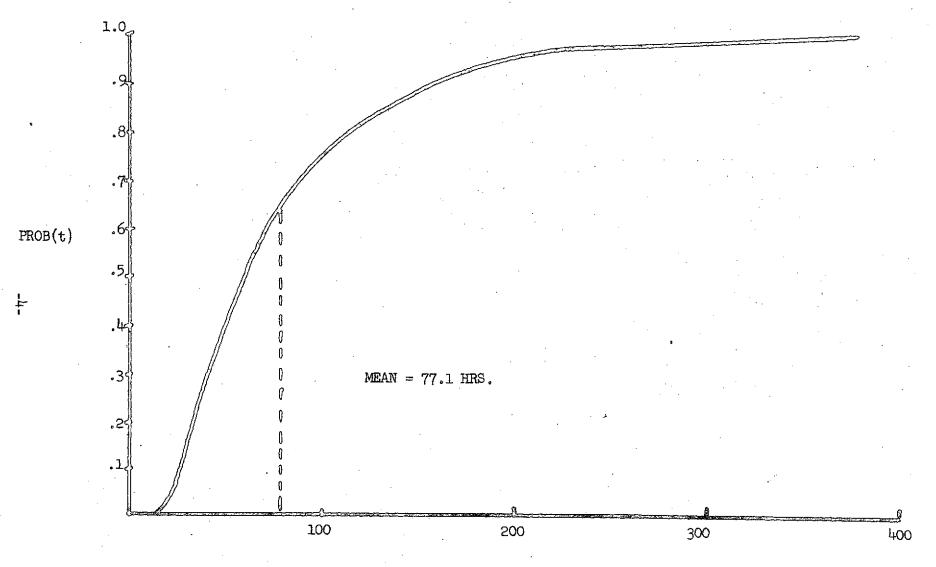
This distribution permitted repair times to vary between zero (0) and five (5) times the specified mean value.

The exponential distribution with a mean value of one (1) was chosen to modify those activities which consisted of basically a troubleshooting and checkout function. This distribution permitted troubleshooting times anywhere from zero (0) to as much as ten (1) times the specified mean value.

The normal distribution was chosen to modify those activities which did not have as large a variation in processing times as those activities previously mentioned. Examples of such activities are transporting, connecting cables, disassembly, etc.

The incorporation of these probability distributions into the model resulted in an overall activity time of 77.1 hours for the SU simulator process. This represents almost a 20% increase over the allocated processing time of 65 hours. Figure 2 presents the distribution of the activity times for the overall SU simulation process.





TIME (t)

FIGURE (2)

CUMULATIVE PROBABILITY DISTRIBUTION
FOR
OVERALL S. U. SIMULATION PROCESS
(SAMPLE CASE -1)

WILEMOTY R

3.0 DISCUSSION (Continued)

Enclosure (1) contains the GPSS simulation model for the SU simulation process (Sample Case 1). The model was exercised for a ten (10) year period in order to achieve a satisfactory sample size. Two separate runs are included to highlight the difference between simulations with and without modifying probability distributions. The model was constructed such that 10 clock units equal 1 hour. Table 1 contains a list of GPSS entities and their association with SU simulation process.

The detailed Level II flow for the SU Simulation Process Sample Case - 2 was also simulated as part of Task No. 2. The same three probability distributions, previously mentioned, were applied in the same manner as before.

The incorporation of these distributions into this flow resulted in an overall activity time of 55 hours for this alternate process. This represents approximately a 10% increase over the processing time if no randomness was considered, i.e. 50 hours. Figure 3 presents the distribution of the activity times for this alternate process.

Enclosure (2) contains the GPSS simulation model for this alternate process (Sample Case 2).

TABLE 1

GPSS Entities used in SU Simulation Model

STORAGE	1	The SU Simulator
QUEUE	1	The waiting line for the SU Simulator
TABLE	1	Presents the time it takes for a payload to pass through the system
TABLE	2	Presents the time that a payload with a discrepancy remains in the system
TABLE	3	Presents the time that the SU Simulator is being tied-up, including servicing



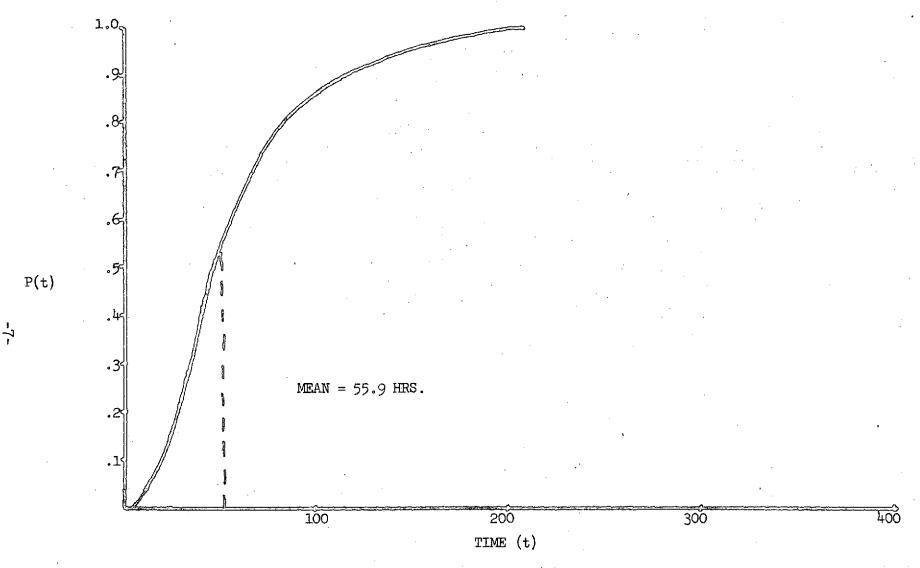


FIGURE (3)

CUMULATIVE PROBABILITY DISTRIBUTION FOR OVERALL S.U. SIMULATION PROCESS (SAMPLE CASE 2)

APPENDIX B

4.0 CONCLUSIONS

In order to meet the allocated processing time of 65 hours for the SU Simulator activity, it is necessary to change the normal concept of an interface simulation process. Sample Case 1, which represents a standard simulation process, takes too long to complete when randomness is introduced into the system. Instead of completing the activity within the allocated 65 hours, it takes greater than 77 hours to complete. This is unsatisfactory. As a result, an alternate process (Sample Case 2) was proposed. This alternate did not use a simulator, but instead made use of the SU itself as a checkout device. The overall processing time for this alternative (with randomness) was 55 hours, well within the allocated 65 hours.

ENCLOSURE (1)

GPSS COMPUTER SIMULATION MODEL

SU SIMULATION PROCESS

SAMPLE CASE 1

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3 MVM 4	ASSIGN TRANSFER ASSIGN TRANSFER ASSIGN TRANSFER ASSIGN ADVANCE ADVANCE TRANSFER ADVANCE	3, KKK FIX1 3, AAA FIX1 3, GSE9 FIX1 5, 30 V2 5, 10 V2 80, FN3	# FROM WHEN_IT. GOES TO MAINT. ###################################	68 69 70 71 72 73 74
5 858 6 7 CCC 6 9 EEE 60 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	TRANSFER ASSIGN TRANSFER ASSIGN TPANSFER ASSIGN ADVANCE ASSIGN ADVANCE TRANSFER ADVANCE TRANSFER ADVANCE	# FIX1 3,AAA #FIX1 3,GSES #FIX1 5,30 V2 5,10 V2 80,FN3	EMUPA NOT COMP REMOVE EMUPA	70 71 72 73 74
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66 7 CCC 66 FEE 60 FEE FEE 60 FEE FEE 60 FEE	TRANSFER ASSIGN TPANSFER ASSIGN ADVANCE ASSIGN ADVANCE ASSIGN ADVANCE TRANSFER ADVANCE	.FIX1 3,GSE9 .FIX1 5,30 V2 5,10 V2 80,FN3	GOES TO MAINT. ###################################	71 72 73 74
7 CCC 6 9 EEE 10 11 12 14 15 16 17 17 18 18 19 10 10 11 10 11 10 11 11 11 11 11 11 11	ASSIGN TPANSFEP ASSIGN ADVANCE ASSIGN ADVANCE ADVANCE TPANSFEP ADVANCE	3,GSES .FIX1 5,30 V2 5,10 V2 .BO,FN3	EMZPA NOT COMP REMOVE EMZPA	72 73 74
66	TPANSFER ASSIGN ADVANCE ASSIGN ADVANCE ADVANCE TPANSFER ADVANCE	FIX1 5,30 V2 5,10 V2 80,FN3	EMZPA NOT COMP REMOVE EMZPA	74
59 FEE 50 51 52 53 54 55 56 57 FFF 68 59 50 51 52 53 50 54 55 57 68 69 KKK 70 71 72 73 111	ASSIGN ADVANCE ASSIGN ADVANCE ADVANCE TRANSFER ADVANCE	5,30 V2 5,10 V2 .80,FN3	EMZPA NOT COMP REMOVE EMZPA	74
50 51 52 53 54 55 57 58 59 50 50 50 50 50 50 50 50 50 50	ADVANCE ASSIGN ADVANCE ADVANCE TRANSFER ADVANCE	v2 5,10 V2 .80,FN3		
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52 53 54 55 56 57 58 59 50 50 50 50 50 50 50 50 50 50	ADVANCEADVANCE TPANSFEP ADVANCE	V2 80.FN3	TRANSPORT EM/PA TO OFF LINE AREA	
63	ADVANCE Transfer Advance	B0.FN3	TRANSPORT EM/PA TO OFF LINE AREA	76
54 55 56 57 58 59 50 50 50 50 50 50 50 50 50 50	TRANSFER ADVANCE			77
55	ADVANCE	∘9,,FFF	DIAGNOSE EM/PA ANDMALIE	78
66			.9 NO REPAIR ON SITE	79
57 FFF 58 59 50 51 52 53 DDD 54 55 57 58 69 KKK 70 71 72 73 ITI 75 HHH		80.FN2	REPAIR ON SITE	80
68 69 65 JJJ 66 67 68 KKK 69 K	TRANSFER.		Approximation of the second of	81
19	ASSIGN	5.20		82
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1	ASSIGN	5,10		8A
22 33 DDD 64 65 JJJ 66 67 68 69 KKK 70 71 72 73 ITI 74 75 HHH	ADVANCE	V2	TRANSPORT TO MAINT ACTIVITY	85
53 DDD 54 55 JJJ 56 57 59 KKK 70 71 72 73 JTT 74	TABULATE	2	TIME FAULTY EM/PA IN SYSTEM	86
63 DDD 64 65 JJJ 66 67 68 KKK 70 71 72 73 ITI 74	TERMINATE		LEAVE SYSTEM	
55 JJJ 66 67 68 69 KKK 70 71 72 73 JIII 75 HHH	ADVANCE	20.FN3	DE-SERVICE MONITOR	. 88
66 67 68 KKK 00 11 12 13 III 14 15 HHH	TRANSFER	*05 . LLL	FAILURE	89
66 67 68 69 KKK 70 71 72 73 JII 75 HHH	ASSIGN	5.15		90
57 58 59 KKK 70 71 72 73 III 75 HHH	ADVANCE	V2	DE-SERVICE COMPLETE AND CERTIFIED	91
58 KKK 70 P1	ADVANCE	10.FN3	POST USE INSPECTION .	
70 71 72 73 III 75 HHH			FAILURE	92
0 1 2 3 III 4 5 HHH 6		5.FN2	OFF LINE SIM MAINT	93
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'5 HHH '6 '	_	15,FN3	PRE SERVICE C/O	98
6 '		05.,CKOT2	FAILURE	
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0		30 • FN3	MONITOR SERVICING	
8	TRANSFER	.1.AAA.BBB	FAILURE	103
9 AAA	ASSIGN	5,10		104
9	A PO 12 A 1 P	Y2	COMPLETE SERVICING	
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5	ASSIGN	٧2	SELF TEST SIMULATOR	107
3		OS.GSES.CCC	FAILURE	
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	ASSIGN ADVANCETRANSFER . ADVANCE ADVANCE	1.GSE1	GIVE THE MALINE	112

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89		ASSIGN	_5。80	444	,			
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.93		LEAVE	3 .	SIMULATOR AVAILABL	E		118	
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		_TERMINATE	·				120	
96	GS E 2	TRANSFER	.17.,GSE6	ONE OF SIX USES			121	
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98	GSE6.	ASSIGN						
99		ADVANCE	٧2	CALIBRATE SIMULATO	R THETON			
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TO1	GSE1	ADVANCE	80.FN3	VALIDATE GSE			125	
1 C S	GSE3	TRANSFER	.25,,GSE5	ONE OF FOUR USES		- 		
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104	GSES	ADVANCE	_160,FN2	MAINTAIN GSE	•		128	
105		TRANSFER	GSE4				1.29	and the second s
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39	CKDIS	99				· · · · · · · · · · · · · · · · · · ·				· ·				
63	DDD	42												
49	EEE	43 <u></u>				,								
57	FFF	79	-											
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TABLE TABLE		ARGUMENT				• • •	
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1050	0 .00	77.9	22.0	1 • 354	.489	
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1065	0 .00	77.9	22.0	1.374	•51 6	
1070		78.A	21.5	1.380 1.387	.525	
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1125	0 .00	80:1	19.8	1.452	.623	
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1235	.53	81.7	18.2	1.594	.820	
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	1 3 3 0	1 .53	84.4	16.1	1.717		
	1 3 3 5	0 .00		15.5	1.724	* 3 9 9	
	1340	_151	84.4	15.5	1.730	1.008	
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•	1365		64.9	15.0	1.763	1.053	
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	1410	1 .53	86.5	13.4		1.133	
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	1455	_	87.0	12.9	1.879	1.214	
	1460	*****	87.0	12.9	1.885	1.223	
	1465	-\$53	87.6	12.3	- 1.892	1.2J2	
	1470	, 400	87.6	12.3	1.899	1.240	and the second s
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	1480	-0	87.6 <i></i>	12.3.	- 1.912	1.258	
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	1495	0 .00	88.7	11.2	1.938	1.285	The state of the s
	1500	0 .00	88.7	11.2		1.294	
	1505	0	88.7	11.2	1.944	1,303	
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	1515	0 .00	88.7	11.2	1.0957	1 # 321	. •
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	1530	1 .53	89.2	11.2	1.977	1.348	•
	1535	0	89.2	10.7	1.983	1.357	
	1540	0 .00	89.2	10.7	1,990	1.366	
	1545	1 .53		10.7	1.996	1.375	
	1550	000	89.7	10.2	2.003	1.384	
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	1935	o	o 0 0	95.6	4.3	2.508	2.081	- 1
······	1940		00	95.6	<u> </u>	2-515	2.090	26
,	945 950	0	.00	95.6	4.3	2.521	2.099	
4	1955	0	.00	95.6	4.3	2.528	2.108	
/ U	1960	^	00	95.6 95.6	4.3 4.3	2.534 2.541	2.117 2.126	
, <i>y</i>	1965	0	.00	95.6	4.3	2.547	2.135	
	1970	0		95.6	4.3	2 · 554	2。144	
	1975		,00	95.6	4.3	2.560	2.153	
	1950	ž.	53،	96.2	3.7	2.567	2.162	
	1985		00	96.2	3.7	2.573	2.171	
	1990	0	.00	96,2	3.7	2.580	2.180	
	1995	0	•00	96.2	3.7	2.586	2.189	,
	2000		00	96.2	3。7	2.593	2,198	
	2005	0	.00	96.2	3.7	2,599	2.207	
	5010	0	.00	96.2	3.7	2.606	2.215	
	2015		00	96.2	3 . 7	2.612	2,224	
	2020	Ö	.00	.96.2	3.7	2.619	2,233	•
	2025	0	۰00	96.2	3.7	2.625	2.242	•
	2030	0		96.2	3. 7	2.631	2.251	
	2035	0	.00	96.2	3 . 7	2,638	2.260	
	2040	0	.00	96.2	3.7	2.644	2,269	
	2045			96.7 96.7	3.2	2 651	2.278	N
	2055	0	.00	96.7	3.2	2 • 657 2 • 664	2.287 2.296	
	2060			96.7	3.2	2.670	2.305	
Marketing of the Angels Wild Andrews Co. 1995	2065	0	.00	96.7	3.2	2.677	2.314	
	2070	Ď	.00	96.7	3.2	2.683	2.323	
	2075			96.7	3.2	2.690	2.332	
	2030	0	.00	96.7	3.2	2 696	2.341	
	2085	Ö	.00	96.7	3.2	2.703	2.350	•
	2090	0	00	96.7	3.2	2.709	2.359	
	2095	D .	.00	96.7	3.2	2.716	2.368	&
₹	2100	0	.00	96.7	3 . 2	2.722	2.376	•
	2105			96	3.2	2.729	2.385	
	2110	. 0	•00	96.7	3.2	2.735	2.394	•
	2115	1	٠53	97.3	2.6	2.742	2.403	
	2120		00	97.3	6.	2。748	2.412	
•	2125	Ó	.00	97.3	2.6	2.755	2.421	
	21 30	. 0	•00	97.3	2.6	2.761	2.430	
	2135	<u>_</u>		97.3	2.6	2°768	2.439	Augustian Lights on the Control of Control of the Control of Contr
	2140	0	• 0 0	97 . 3	2.6	2.774	2.448	•
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	2150	D		97.3	2,6	2.787	2.466	
	2155	0	•00	97.3	2.6	2.794	2.475	
	2160	0	.00	97.3	2.6	2.800	2.484	
	2170	0	.00	97.3	2.6	2,807 2.813	2,493 2.502	
	2175	. 0	• 00	97.3	2.6			•
•	2180	n ·	00	97.3 <u>·</u>	2.6	2.819 2.825	2.511 2.520	
	2185	0	.00	97.3	2.6	2.832	2.529	
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· ·	2200	0	-00	97.3	2.6	2.852	2.555	
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	2210		00	97.3	2.6	2.965	2.573	
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ra. 5	2220	å	•00	97.3	2.6	2.878	2.591	
À	2225	0		97.3	2.6	2.884	2,600	and the second s
1	5830	. 0	•00	97.3	2.6	2 - 891	2.609	
,	2235	0	.00	97.3	2.6	2.897	2.618	•
	2240			97.3	2.6	2.904	2,627	
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2295 0 23000		97.3	2.6	2,975	2.725	·
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2310 0	• 0 0 • 0 0	97.3 97.3	2.6	2.988	2.743	
2315		97.3	2.6	2.995 3.001	2.752	
2320	•53	97.5	2.1	3.001	2.761 2.770	
2325 0	-00	97.8	2.1	3.014	2.779	
2335 a	.00	97.8	2.1	3,020	2.788	and the second s
2340 0	•00	97.8 97.8	2.1	3.027	2.797	·
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2350 0	.00	97.8	2.1	3,040 3,046	2.815	
2355 0	•00	97.8	2.1	3,053	2.824 2.833	
2360 0		97.8	2.1		2.633 2,842	
2365 0 2370 0	****	97.8	2.1	3.066	2.851	
2370 0	.00	97.8	2.1	3.072	2.859	
2390 0	.00	97.8 97.8	2.1	3.079	2.868	
2385 0	•00	97.8	2 • 1 2 • 1	3.085 3.092	2.877	
23900	.00	97.8	2.1	3.092 3.098	2.886 2.895	·
2375 g	•00	.97.8	2.1	3.105	2,904	
2400 0		97.8	2.1	3.111	2.913	
2410	.53	97.8	2。i		2,922	
2415	۶53 ۵00	5.86 F.80	1.6	3.124	2.931	
24200		E.89	1.6	3.131	2.940	· · · · · · · · · · · · · · · · · · ·
2425	,00	98.3 98.3	1.6	3。137 3。144	2.949	
2430 0	.00	98.3	1.6	3.144 3.150	2.958 2.967	
24 35		98.3	1.5		2.967 2.976	
2440 0 2445 0	.00	98.3	1.6	3.163	2.985	
2445 0		98.3	1.6	3.170	2.994	
2455 0	.00			3.176	3,003	
2460 0	,00	98.3 98.3	1.6	3.182	3.012	•
24650		98.3 98.3	1.6	3.189 3.195	3.020	
2470 0	.00	98.3	1.6	3,202	3.029 3.038	-
2475 0	.00	96.3	1.5	3.208	3.047	
2480				3.215	3.056	
2485 0 2490 0	, 00 - 00	98,3	1.6	3.221	3.065	
2495 0	.00	98.3 98.3	1.6	3.228	3.074	
2500 0	.00	98.3		3.234	3.083	
2505 0	•00	98.3	1.6 1.6	3.241 3.247	3.092 3.101	
2510 0		98•3	1.6	3.254 <u></u> .	3.101 3.110	•
2515 0 2520 0	.00	98.3	1.6	3.260	3.119	*
2520 0	• • • • • • • • • • • • • • • • • • • •	98+3	1.6	3.267	3.128	
2530	.00	98.3		3 . 273	3.137	
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		98•3 98•3	1+6	3.286 3.293	3.155	
2545 0	.00	98.3	1.6	3.293	3.164 3.173	
2550 0	•00	98.3	1.6	3.306	3.181	
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2550 0 2565 0	•00	98.3	1.6	3,319	3.199	- Company of the Addition of the Company of the Com
A	•00	98.3	1 • 6	3.325	3.208	
2575 0	•00	98.3 98.3	1.6	3.332 3.330	3.217	and the second of the second o
2580 0	•00	98.3	1.6 1.6	3.338 3.345	3.226	
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2595 0	.00	96.3	1.6	3.360	3,262	خير
2600 0		98,3		3.370		
2605		98.3	1.6	3.377	3.280	
2615	000	98.3	1.6 .	3.393	3.289	
2620 0	.00	98.3	1 , 6	3,390	3,298	
2625 n	٥٥٥ م	98.3	1.6	3.396	3.307	
2630		98.3 98.3	1.6	3.403	3.316	
2635 0	•00	98.3	1.6	3,409	3,325	,
· 2640 o		98.3	1.5	3.416 3.422	3.334	
		98.3	1.6	3,429	3.342 3.351	
2650 0	.00	98.3	1.6	3.435	3,360	
2655 0	• 0 0	98.3	1.6	3.442	3.369	
2650 0 2665 0	00	98.3	1.6	3,448	3,378	·
2665 0 2670 p	. O O	98.3	1.6	3.455	3.387	
2675	•00	98.3	1.5	3.461	3.396	
2680 g	.00	98.3	1.6	3,468	3.405	
2685 n	.00	98.3 98.3	1.6	3.474	3.414	
2690		98.3	1.6	3.481	3.423	
2695 0	•00	98.3	1.6	3。487 3。494 .	3,432	
2700 0	.00	98.3	1.6	3,494	3.441 3.450	
2705	00	98.3		3°507	3,459	
2710 0	.00	98.3	1.6	3.513	3.468	
2715 0	.00	98.3	1.6	3.520	3.477	
2720 0		98.3	1.6	3.526	3,486	
2725 0 2730 0	.00	98.3	1.6	3,533	3.495	
2735	.00	98.3	1.6	3,539 .	3.503	
2740	000	98.3		- 3°546	3.512	en e
2745	.00	98.3	1.5	3.552	3.521	•
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2755 0	٥٥٥	98.3			3.539	
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27650			1.6	3,578 3,584	3.557	
2770 0	.00	98.3	1.6	3,591	3.566	the same of the same and the sa
2775 0	.00	98.3	1.6	3.597	3.575 3.584	
27800	00	98.3	1 . 6	3.604	3.593	
2785	.00	98.3	1.6	3,610	3.602	
2790 0 	•00	98,3	1.6	3.617	3.611	
	00			3,623	3.620	
2800 0 2805 0	.00	98.3	1.6	3,630	3.629	
28101	.00	98.3	1.6	3,636	3.638	
2815 0	.00	98.9 98.9	1.0	3.643	3.64.7	
2820 0	• 0 0	98.9	1.0	3,649	3,656	
2825	00	98.9	1.0	3.656 3.662	3.664	
2830 0	•00	98.9	1.0	3,669	3.673	
2835	•00	98.9	1.0	3,675	3.682 3.691	
29400	00	98.9	1.0	3.682	3.700	
2945	•00	98.9	1.0	3,688	3.709	
2850 0 2855 0		98.9	1.0	3 • 695	3.718	
2860 p	.00	98.9	1.0	ior.E	3. 72 7	
2865 0		98.9	1.0	3,708	3,736	
2870	•00	98.9	1.0	3.714	3.745	
2975 0	■00	98.9	1.0	3.721	3.754	
2990 0	.00	98.9	1.0	3.727	3.763	
2885 0			. 1.0 1.0	3.734	3.772	•
2.890.	•00	98.9	1.0	3.740 3.746	-: ·3.781 ·· · ·	entropy of the second of the s
2895 0	• 0 0	98.9	1.0	3.753	3.790 3.799	
A 2900 0		ــــــــــــــــــــــــــــــــــــــ	1.0	_ 3.759	3.808	
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	25 0		99.4	•5	3.792	3,852	Z
	300					3.86	
Y 11	935 0	00	99.4	.5	3.805	3.870	
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-	150 o	800	99.4	۰5	3.824	3.897	
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	955 0 970 0	, , , , , , , , , , , , , , , , , , , ,	99.4	۰5	3.844	3,924	
	770 <u>.</u> 375	, 0 <u>0</u>	99.4	5 ه	3 - 450	3,933	
	990		99.4		3.857		
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	95 0		99.4	.5	3.883	3.978	
	000	٥٥٥	99,4	. 5	3.889	3,986	
3o	0050	0.0	99.4		3.896		
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	5.266	4.816	5	99.4	٥٥٥	o	3715
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9103K 		OPERATION SIMULATE	A, B, C, D, E, F, G	COMMENTS		CARD NUMBE	R.
	C,1/1.	FUNCTION	RN1,D2 CONST	AN T			1 2
		FUNCT ION	RN1,D2 CONST	AN T			3
· · · · · · · · · · · · · · · · · · ·		FUNCTION	au1, D2 _CONSTAN	T		a continue of the continue of	5 6
	0,27.3	FUNCTION 23,33/.067.	RN1,C29 NORE 507,115,587,159.6	677,184,707,919,737			8 70
	450,3	1/.2/4,80/. 6/.5,100/.5	.393,83/.345,87/.; .40.104/.579,107/.	382,90/.421,93/ .618.1107.655.1137		1	0
		177.726,120	/.758,123/.788,12 /.933,150/.977,16	277,816,1307	· · · · · · · · · · · · · · · · · · ·	1	2
	1	TABLE	11,7,5,1000 11,0,5,1000	TIME EM/PA IN SIM R TIME FAULTY EM/PA I	OUPINE	⁷ 1	4
	3	TABLE STORAGE	11,0,5,1000	TIME SU SIM IS TIED SU SIM	UP UP		6
	1	VARIABLE FVAPIABLE	P2+4 P5 * CONS	TRANSACTION CONTROL		1	8
1		FVARIABLE GEVERATE	P5*33/100*PN4/10 4363,,1,,,P	DO * DISTRIBUTION 20 MISSIONS A YEAR	•	1 2	0
3	ggg -	ASSIGN TRAUSFER	1,0 ,EBAN1			2 2	2
<u>4</u>	TE NU 2	ADVANCE	9	TRANSP. NOT COMP # DUMMY # BLOCK	,		4 -
6 7.		ASSIGN NARK	2, T RAN2	* BLOCK		2 2	
8		ASSIGN ADVANCE	5,30 V2	Thomas		2	
10 -		QUEUE ENTER	1.	INSTALL & ASSEMBLE WAIT FOR SU SIM	EM/PA	2	
12 13	ក្ រាជ្ធ ស	DEPART ASSIGN	1 5,50	GZT SIMULATOR		3 3	
15	E # 10F.	ADVANCE ADVANCE	٧2	POWER UP SIM.		3	
16		ADVANCE	410, 2 N3 100, 2 N3	ETRI ARVME RCTINOM OND ARVME ETELEMOD		3 	
18		SPLIF TRANS FER TABULATE	1,000 1,,%EE	SIMULTANEOUSLY SER .1 NOT COMPATIBLE	VICE SU SIN	3	
20 21		ASSITH ADVANCE	5,30	TIME EM/PA ON SIM	· · · · · · · · · · · · · · · · · · ·	4(9
22 23		ASSIJH ADVANCE	V2 5,10 V2	REMOVE AND DISASSE	MBLE FROM SIM	4.	1
24 25	ጥር ኢላ 1	TERMINARE ASSIGN	5,20	TRANSPORT		4.	
26 27	······································	ADVANCE ASSIGN	v2 5, 10	INCOMP. TRANS CO	N GSE	4.	
. 28 29	(-2)	ADVANCE	V 2	REMOVE ZM/PA		4 :	7 3
3'0 31	0	ASSIJN MARK	2, T RAN1			45	
32		ASSIGN ADVANCE	5,60 V2	INSTALL AND ASSEMBL	LE EM/FA	5:	1
3.5 3.5	*****	OUEU: ENTER	1	WAIT FOR SU SIN GET SIMULATOR		5. . 5 .	
, ,		DEPART	,		*	55	5 · · · · · · · · · · · · · · · · · · ·

		PRANS PER	. 5 M 3 D B			56	•	•
	CKOLL	ASSIGN	3,III		- mar - r - 	57_		
		TPANS FER	,FIX1	# · · · · · · · · · · · · · · · · · · ·		56		
	Ck 3 55	ASSIGN	3,888	\$	•	59		
		PPANS FEE	, FIX1	* IDENTIFY WHERE		60		
	LLL	ASSIGN	3,333	¢		61		
		TPANS FEB	, PIX1	◆ TRANSACTION CAME		6.2	•	
	K 4.4	ASSIGN	3,888	**************************************		6.3		
		TPANS FER	,FIX1	* FROM WHEN IT		64		
	BBB .	ASS IGN	3, AAA	*		65		
		TPANSFER	,FIX1	GOES TO MAINT.		66		
	ecc	ASSIGN	3,GS28	. #		67		
		trans feb	,FIX1	‡		68	`	
	753	ASSIGN	5,30			6.9		
		ADVANCE	V 2	EM/PA NOT COMP REMOVE EM/PA	The state of the s	70		
		ASSIGN	5,10			71		
		ADVANCE	V 2	THANSPORT EM/PA TO OFF LINE AREA	•	72		
		ADVANCE	BO, FN3	DIAGNOSE EM/PA ANOMALIE		73		· Samuel and Advance of the same of the sa
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TABLE 1 ENTRIPS IN	TABLE	MEAN ARGUMENT 054.632	STANDARD DEVIAT	ION SUM_OF	ARGUMENTS	NON-WEIGHTED -
TABLE 2 ENTPLES IN 1	[A3LE	MEAN ARGUMENT 837.272	STANDARD DEVIATIO	N SUM OF A	RGUMENTS	SON-HEIGHTED
TABLE 3 TENTRIES IN	TABLE	MEAN ARGUMENT 1008.905	STANDARD DEVIAT. 239.		ARGUMENTS 202790.000	NON-WEIGHTED
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955	0	99,4	.5 1.466 5 1.474	4.960 5.041	
970 975	00.00	99.4	1.481	5.122	
930	00.00	99.4	.5 1.469	5.203	
735	0 .00	99.4		5.265	
295 235	0 .00	99.4	.5 1.504 .5 1.512	5.366 5.447	
1370	.00	99.4	.5 1.519	5.528	
1005	00 .00	99.4	1.527	5.610	
1010	0 .00	99.4	.5 1.535 .5 1.542	5.691	•
1015	0 .00	99.4	.5 1.542 .5 1.550	5.772 5.853	
1920 1925	0 .00	99.4	.5 1.558	5.934	
1030	0 .00	99.4	.5 1.565	6.016	
1935	0 .00	99.4	.5	6.097	
1140	0 .00	99.4	.5 1.581 .5 1.588	6.178	•
1045 1050 -	00.00	99.4	1.596	6.259 6.340	Service of the servic
1005	0 .00	99.4	.5 1.603	6.422	
1767	0 .00	99.4	.5 1.611	6.503	
1065	0 .00	99,4	.5 1.619 .5 1.626	6.584	
1070	0 .00	99.4	.5 1.626 .5 1.634	6.665	
1775	0.00	99.4	.5 1.642	6.747	4
1090 1055	0 .00	99.4	.5 1.649	6.909	
1790	0 .00	99.4	.5 1.657	6.990	•
1035	0 .00	99.4	.5 1.665 .5 1.672	7.071	
1100	0 .00	99.4	.5 1.672 .5 1.680	7.153	·
1195	0 .00	99.4	1.697	7.234 7.315	
1110 	0 .00	99.4	.5 1.695	7.396	
1129	00 .00	99.4	.5 1.703	7.47a	*
1125	0 .00	99.4	.5 1.710	7.559	
1130	0 .00	99.4	.5 1.718 .5 1.726	7.64C	
1135	0 .00	99.4	.5 1.733	7.721 7.802	<u> </u>
1140 1145	0 .00	99.4	5 1.741	7.884	
1150	0 .00	99.4	1,749	7,965	
1155	0 .00	99.4	.5 1.756 .5 1.764	8.046	
1160	000	99.4	.5 1.764 .5 1.771	8.127 8.209	
1155 1170	.00	99.4	1.779	8.290	
1175	0 .00	99.4	. 5 1,787	8.371	
1180	ŏ .00	99.4	.5 1.794	8.452	
	0 .00	99.4	.5 1.802 .5 1.810	8,533	The state of the s
1190	.00	93.4	.5 1.317	8.615 8.696	
1195 1200	0 .00	99.4	1.325	8.777 · · · · · · · ·	
1295	0 600	99.4	.5 1.833	8.858	
1210	° .00	99.4	.5 1.840 .5 1.848	E.939	
	.00	99.4	.5 1.848 .5 1.856	9.021	· · · · · · · · · · · · · · · · · · ·
1220	00.00	99.4	.5 1.863	9.102 9.163	
1 230	0 .00	99.4	.5 1.871	9,264	the second secon
	00 00	99.4 99.4	.5 1.87s	9.346	•
<u> የ</u> .၅ 1240	0		.5 1.386 .5 1.894 "	9.427	
· A 1243	0 .00	99.4	.5 1.894 " .5 1.901	9.50a	•
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	0 .00 00	99,4	.5 1.924	9.833	
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0 .00 .99.4 .5 1.955 10.156 0 .00 .99.4 .5 1.962 10.239 0 .00 .99.4 .5 1.970 10.320 0 .00 .99.4 .5 1.985 10.461 0 .00 .99.4 .5 1.985 10.645 0 .00 .99.4 .5 2.001 10.645 0 .00 .99.4 .5 2.003 10.726 0 .00 .99.4 .5 2.016 10.807 0 .00 .99.4 .5 2.033 10.726 0 .00 .99.4 .5 2.031 10.697 0 .00 .99.4 .5 2.031 10.697 0 .00 .99.4 .5 2.031 10.697 0 .00 .99.4 .5 2.039 11.061 0 .00 .99.4 .5 2.0				5	99.4			1275
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9 .00 99.4 .5 1.970 10.320 0 .00 99.4 .5 1.978 10.401 0 .00 99.4 .5 1.985 10.463 0 .00 99.4 .5 1.985 10.463 0 .00 99.4 .5 1.985 10.465 0 .00 99.4 .5 2.001 10.645 0 .00 99.4 .5 2.001 10.645 0 .00 99.4 .5 2.016 10.807 0 .00 99.4 .5 2.016 10.807 0 .00 99.4 .5 2.034 10.976 0 .00 99.4 .5 2.031 10.976 0 .00 99.4 .5 2.031 10.976 0 .00 99.4 .5 2.039 11.051 0 .00 99.4 .5 2.039 11.051 0 .00 99.4 .5 2.086 11.322 0 .00 99.4 .5 2.086 11.376 0 .00 99.4 .5 2.086 11.376 0 .00 99.4 .5 2.089 11.376 0 .00 99.4 .5 2.089 11.376 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.086 11.761 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.092 11.620 0 .00 99.4 .5 2.092 11.620 0 .00 99.4 .5 2.100 11.701 0 .00 99.4 .5 2.100 11.701 0 .00 99.4 .5 2.100 11.701 0 .00 99.4 .5 2.115 11.663 0 .00 99.4 .5 2.115 11.663 0 .00 99.4 .5 2.130 12.026 0 .00 99.4 .5 2.130 12.026 0 .00 99.4 .5 2.130 12.026 0 .00 99.4 .5 2.130 12.026 0 .00 99.4 .5 2.161 12.351 0 .00 99.4 .5 2.161 12.351 0 .00 99.4 .5 2.161 12.351 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.176 12.513 0 .00 99.4 .5 2.184 12.594 0 .00 99.4 .5 2.184 12.594 0 .00 99.4 .5 2.192 12.676 0 .00 99.4 .5 2.192 12.676 0 .00 99.4 .5 2.192 12.676 0 .00 99.4 .5 2.192 12.676 0 .00 99.4 .5 2.222 13.000				.5			·. (12 ± 5 12 ± 5
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7 .00 99.4 .5 1.985 10.483 0 .00 99.4 .5 1.983 10.564 0 .00 99.4 .5 2.001 10.645 0 .00 99.4 .5 2.016 10.266 0 .00 .99.4 .5 2.016 10.465 0 .00 .99.4 .5 2.031 10.677 0 .00 .99.4 .5 2.031 10.976 0 .00 .99.4 .5 2.031 10.51 0 .00 .99.4 .5 2.031 10.51 0 .00 .99.4 .5 2.031 11.51 0 .00 .99.4 .5 2.054 11.132 0 .00 .99.4 .5 2.054 11.295 0 .00 .99.4 .5 2.062 11.295 0 .00 .99.4 .5 2.077			1.978					1255
9	ي بيرياء ومستبرو سنشد الدام الوقا المساويات الد		1.985	.5			9	9300 *** 00
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0 .00 99.4 .5 2.024 10.dd9 0 .00 99.4 .5 2.031 10.970 0 .00 99.4 .5 2.039 11.051 0 .00 99.4 .5 2.039 11.051 0 .00 99.4 .5 2.046 11.132 0 .00 99.4 .5 2.054 11.214 0 .00 99.4 .5 2.062 11.295 0 .00 99.4 .5 2.062 11.376 0 .00 99.4 .5 2.069 11.376 0 .00 99.4 .5 2.089 11.538 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.085 11.538 0 .00 99.4 .5 2.000 11.701 0 .00 99.4 .5 2.000 11.701 0 .00 99.4 .5 2.100 11.701 0 .00 99.4 .5 2.102 11.620 0 .00 99.4 .5 2.102 11.663 0 .00 99.4 .5 2.115 11.663 0 .00 99.4 .5 2.115 11.663 0 .00 99.4 .5 2.123 11.945 0 .00 99.4 .5 2.130 12.026 0 .00 99.4 .5 2.130 12.026 0 .00 99.4 .5 2.138 12.107 0 .00 99.4 .5 2.138 12.107 0 .00 99.4 .5 2.138 12.107 0 .00 99.4 .5 2.153 12.269 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.161 12.351 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.169 12.432 0 .00 99.4 .5 2.192 12.676 0 .00 99.4 .5 2.192 12.676 0 .00 99.4 .5 2.199 12.757 0 .00 99.4 .5 2.199 12.757 0 .00 99.4 .5 2.199 12.757 0 .00 99.4 .5 2.199 12.757 0 .00 99.4 .5 2.227 12.838 0 .00 99.4 .5 2.222 13.000	•			• 5			5	1925 1925
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ENCLOSURE (2)

GPSS COMPUTER SIMULATION MODEL

SU SIMULATION PROCESS

SAMPLE CASE 2

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Arnerst.	S. GILMARTIN BL	T_25 %CASE_2#	·		[******* C A L L D A T A *******************************				
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LOG VESENGE	and the second s	بسويون واستربيست سويت المائد والمائد							
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					GG				
					GG GG DD I*V SSS				
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#### OPS MODEL STUDY

#### APPENDIX C

#### AUTOMATION OF MODELING TECHNIQUES

REPORT NO. SU OPS-RP-73-0002C

PREPARED FOR THE

GEORGE C. MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA

CONTRACT NUMBER
NAS 8-30302

PREPARED BY

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., N. Y.

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# OPS MODEL STUDY

# APPENDIX C

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#### 1.0 STUDY TASK

This task examines the feasibility of automating modeling te techniques for the purpose of determining capacities and quantities.

#### 2.0 INTRODUCTION

NASA has found themselves in a situation where a requirement exists to perform a large number of computer simulation runs. Each one of these runs postulate and examine a different "what if" situation. For example, various quantities of support modules, pallets, tunnels, experiment modules, maintenance facilities, etc. must be analyzed to determine the effect on the overall Sortie Lab's avility to meet the mission requirements.

Because of the constraints and limitations involved in the use of their computer systems (UNIVAC 1108 and the IBM 7094) NASA has found it desirable to automate their computer simulation runs. Essentially this involves the automatic passing of output statistics from one run to the next run in order to establish new constraints on the system. Normally this passing of information is accomplished by introducing a man into the loop. He examines the output statistics from a given simulation run, establishes new constraints based on these statistics, introduces the new constraints into the simulation model and then runs the new "what if" condition. This process is repeated over and over many times until all of the viable alternatives are analyzed. This iteration technique rapidly becomes very tedious when even a moderate number of variables are being analyzed, because the number of different combinations becomes unwieldy

#### 2.0 INTRODUCTION (continued)

GAC has performed an analysis to determine the feasibility of automating the GPSS computer simulation runs. Different techniques were tried and the results are presented in the discussion which follows.

#### 3.0 <u>DISCUSSION</u>

Two different approaches were tried to automatically determine an optimum size or capacity of various equipment or facilities ("STORAGES") within the model.

The first approach was to run the model unconstrained in the first simulation. Upon completion, place the maximum contents of a given "STORAGE" into a "SAVEVALUE" where it could be passed to the next run after a selective "CLEAR" or "RESET" card. In the second simulation (after the "CLEAR" or "RESET") the contents of the "SAVEVALUE" "j" (X_j) was then referred to in the storage definition card. This unfortunately was unsuccessful. The storage definition card cannot have an argument indirectly addressed or specified. The capacity of the, "STORAGE" wound up being the Value "j" rather than the contents of "SAVEVALUE"-j.

A slight variation of the above was also tried. Instead of using the contents of SAVEVALUE "j" as the argument of the storage definition card, a VARIABLE statement was used. This approach proved unsuccessful as did the above for the same reason.

The second approach was similar to the first in that the maximum contents of a given "STORAGE" under study was placed in a "SAVEVALUE" and passed to the next sequential run. This time, instead of trying to use the data in the "SAVEVALUE" directly as the capacity, the storage was pre-loaded by an amount equivalent to the old capacity less the value in the "SAVEVALUE" X₁.

-2-

#### EXAMPLE:

RUN - 1

INPUT: Capacity Store #2 = 100 (larger than necessary

essentially unconstrained)

OUTPUT: MAX Contents = 5

SAVEVALUE #1 = 5.

RESET (or CLEAR X1)

RUN - 2

INPUT: Capacity Store #2 = 100

Preload Store #2 with 95 (100-5) Units

Filter Out Transactions from RUN -1

OUTPUT: MAX Contents = 5 (same as RUN -1)

Observe Mission Reqmt's still being met

RESET (or clear X1)

RUN - 3

INPUT: Capacity Store #2 = 100

Preload Store #2 with One (1) more than

Run - 2 (95 + 1 = 96)

Filter out transactions from RUN -2.

OUTPUT: Observe Mission Reqmt's still being met

Reset (or clear X1)

RUN - 4

(END)

INPUT:

Capacity Store #2 = 100

Preload Store #2 with one (1) more than previous run

Filter out transactions from previous run

OUTPUT: Observe Mission Reqmt's still being met
Reset (or clear X1)

This approach was reasonably successful in that the specified objective was accomplished, that is, the effective capacity of the "STORAGE" was determined based upon the output of a previous simulation The output statistics for the "STORAGE" in question, however, become distorted since the STORAGE had contained 95 dummy Transactions from time "t"=0.

The statistics that resulted can be & were modified "off line" to reflect the desired situation (capacity of storage #2 = 5, 4, 3,... ---). Enclosure 1 contains a sample GPSS simulation model. Four sequential simulations were run, utilizing the RESET card to end one run & initiate the next.

The storage statistics were modified as per the following formulas:

CAPACITY (MOD.) = SAVEVALUE 1 (for 2nd run, decreasing by 1 each sequential run)

AVG. TIME PER TRANS, (MOD.) = MEAN FROM TABLE #1

ENTRIES (MOD.) = # ENTRIES IN TABLE

AVG. CONTENTS (MOD.) = AVG TIME PER TRANS (MOD) X ENTRIES (MOD)/CLOCK

AVG. UTIL (MOD.) = AVG CONTENTS (MOD.)/CAPACITY (MOD)

MAX CONTENTS (MOD.) = MAX CONTENTS - PRELOAD

# RUN - 1 (STATISTICS NOT MODIFIED)

# STORE - 2 CAPACITY (MOD.) - 100 AVG. TIME PER TRANS (MOD) - 25.25 ENTRIES (MOD) - 287 AVG CONTENTS (MOD) - 2.415 AVG UTILIZATION (MOD) - .024 MAX CONTENTS (MOD) - 5

## RUN - 2

#### STORE - 2

CAPACITY (MOD)	-	5 (100 - 95)
AVG TIME PER TRANS (MOD)	-	25.202
ENTRIES (MOD)	-	292
AVG CONTENTS (MOD)	-	2.45 (25.202 x 292/3000)
AVG UTILIZATION (MOD)	-	49% (2.45/5)
MAX CONTENTS (MOD)	-	3 (98 - 95)

#### RUN - 3

### STORE - 2

CAPACITY (MOD)	- 4 (5 - 1)
AVG TIME PER TRANS (MOD)	<b>-</b> 25.506
ENTRIES (MOD)	- 302
AVG CONTENTS (MOD)	- 2.56 (25.506 x 302/3000)
AVG UTILIZATION (MOD)	- 64% (2.56/4)
MAX CONTENTS (MOD)	- 4 (100 - 96)

# RUN 🕳 4

STORE - 2

CAPACITY (MOD) - 3 (5 - 2)

AVG TIME PER TRANS (MOD) - 24.887

ENTRIES (MOD) - 293

AVG CONTENTS (MOD) - 2.42 (24.887 x 293/3000)

AVG UTILIZATION (MOD) - 81% (2.42/3)

MAX CONTENTS (MOD) - 3 (100 - 97)

It should be pointed out that a "RESET" card, rather than a "CLEAR" card was chosen to separate and reinitiate the different simulations. The "RESET" card in GPSS-III & GPSS-1100 does not alter the contents of "SAVEVALUES" whereas the "CLEAR" card does, it sets everything to zero, including all SAVEVALUES. However, the use of the "RESET" rather than the "CLEAR" creates problems. Besides not destroying the contents of SAVEVALUES it does not destroy any transactions in the model being processed at the time of termination and it sets the storage entry count & maximum contents to the current contents of the store at the time of termination. Both of these characteristics must be negated by programming techniques in order to successfully automate the simulation runs.

First, a "LEAVE" block must be inserted at the very end of the simulation ("t" = 3000) to set the current contents to zero.

When the next sequential simulation starts the entry count & maximum contents of the storage will be set to zero (0), instead of picking up the current contents at the end of the previous simulation.

Second, an "ASSIGN" block is used to identify each transaction as belonging to Simulation Run 1, 2, 3, or 4. This is accomplished changing the "B" field of the ASSIGN block for each simulation. A "TEST" block is also used in conjunction with the "ASSIGN" block to filter off any transactions being passed from the previous run.

Third, a table is utilized to measure the transit time through the STORAGE. Both, a "RESET" & "CLEAR" card tend to cause erroneous STORAGE out statistics. The average time per transaction can be

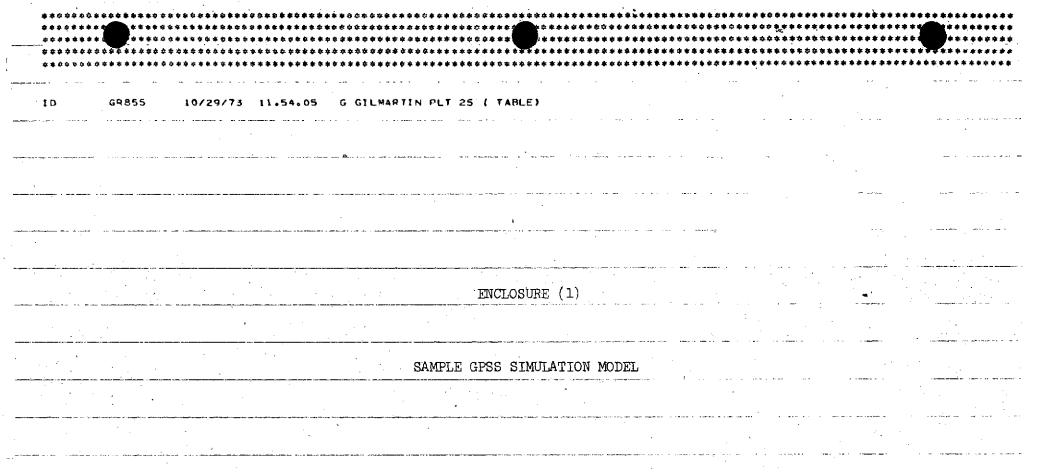
lower than the true value. (Note: This is explained in the GPSS-III users Manual; page - 163). The use of a table to measure the average transit time of a transaction through a storage enables the analyst to access the true AVERAGE TIME PER TRANSACTION.

It should be noted that in other versions of GPSS, such as GPSS-360, a selective CLEAR card can be used to separate the different simulation runs. Field "A" of this card specifies which SVAEVALUES should not be changed to zero (0). This selective CLEAR offers the advantages of not having to filter out transactions from the previous run and not having to set the storage to zero before the run terminates.

#### 4.0 COURSE OF ACTION

The above technique allows the analyst to pass data from one simulation to the next, using this data as constraints in the following runs. The problem remains, however, to determine which storages should be examined, and in what order.

Presently, cost seems to be the determining factor. Those STORAGES which represent high cost facilities should be examined first followed by the less costly facilities. The task still remains to determine how this system of priorities should be integrated into the simulation model.



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9			LEAVE	2				17		
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15			TERMINATE					23		
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17		GHI	ENTER	2.71				25		
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13		ARC	SAVEVALUE	2 . SM2	•			31	•	• .
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16		DEF	GENERATE				•	32		
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			RESET			and a state of the second district and the second s		35		
2		JKL	ASSIGN	1+3				36		
	IPLE			MBOL IN ABOVE CARD						
3			TEST GE	P1,3,P0R	•			37		
13	IPLE	ARC	SAVEVALUE	MBOL IN ABOVE CAPD						
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16		DEF	GENERATE	***1*10		• •		39	-	
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17		GHI	ENTER	2.V2				40		· · · · · · · · · · · · · · · · · · ·
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MA.2				1 - 4	· ·			42		
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·- * ·	2	0	•00	.0	100.0			
	3	Ó	.00	•0	100.0		~3.892 -3.725	
	4	0	•00	• 0	100.0		-3+725 -3+558	
	5	0	•00	.0	100.0		-3.392	
	6	0	•00	. 0	100.0	·197	-3.225	
	7	0	.00	•0	100.0		-3.058	
	8	1 0	.00	.0	100.0	75 75-50	-2.891	
•	9	0	.00	•0	100.0		-2.724	
	10	. 0	.00	-0	100.0		-2.557	
	14	0	.00	•0	100.0		-2.390	· · · · · · · · · · · · · · · · · · ·
	12		.00	•0	100.0		-2.223	
- "	13	0	.00	-0	100.0		-2.223	
	14	0	•00	.0	100.0		-1.889	
	15	15	5.26	5.2	94.7		-1.722	
	16	9	3.15	8.4	91.5	,	-1.555	
	17	10	3.50	11.9	68.0	the second contract of the second	~1.388	and the second s
	18	12	4.21	16.1	83.8		-1.221	
	19	11	3.85	19.9	80.0		-1.054	
	20	17	5.96	25.9	74.0		Transaction of the same of the	Annual Commission of the Commi
•	21	111	3.85	29.8	70.1	- · ·	887	•
	22	19	6.66	36.4	63.5		÷.720	
	23	12	4.21	40.7	59.2		~ • 553	
	24	20	7.01	47.7	52.2		356	
	25		3.15	50.8	49.1		219	
	26	15	5.26	56.1		the same and the s	052	
	27	11	3.85	59.9	43.8		.114	
	28	13:	4 • 5 6	64.5	40.0		- 281	
	29	19	6.66				.448	<u></u>
	30	9	3.15	71.2 74.3	28.7		•615	
	31	18	6.31	80.7	25.6		.782	
	38	io i	3.50		19.2	the state of the s	949	
	33	17	5.96	. 84 • 2 90 • 1	15.7		1.116	
	34	11	3.85	90 • 1	9.8		1.283	
	35	17			5.9	Commence of the contract of th	1.450	
		k f	5,96	1.00.0	.0	1.382	1.617	

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2	. 0	291 291	11 12	0	292	•	•			-			
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CONTENTS OF FULLWORD SAVEVALUES (NON-ZERO)

QUEUE MAXIMUM AVERAGE CONTENTS CONTENTS TOTAL · ZERO AVERAGE PERCENT SAVERAGE TABLE CURRENT ENTRIES ENTRIES ZEROS TIME/TRANS TIME/TRANS NUMBER CONTENTS 1 .000 291 291 100.0 SAVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

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. 3	0	•00	• O	100.0	.079	-3.907	
4	0	. 00	• 0	100.0	•119	-3,739	
5				100.0	•158	-3.570	-
. 6	ő	•00	•0	100.0	•19B	-3.402	The second secon
7	ò	•00	• 0	100.0	•238°	-3.234	
8	0			100.0	277	-3.065	
9	ă	•00	• 0	100.0	<b>*317</b>	-2.897	
_ 10	Ó	•00	• 0	100.0	-357	-2.728	
11	0	•00	**************************************	100.0	• 396	-2.560	
12	. 0	•00	• O	100.0	•436	-2.391	The second of th
	0	•00	.0	100.0	.476	-2.223	
14	0	•00	-0	100.0		-2.055	
15	18	6.16	5.1	100.0	•555	-1.886	
16	14	4.79	10.9	93.8	•595	-1.718	
L7	А	2.73	13.6	89.0		-1.549	
18	5	1.71	15.4	86.3	<b>a</b> 674	-1.381	
	20	6.84	22.2	84.5	714	-1.212	
20	10	3.42	25.6	77.7	•753	-1.044	
21	12	4.10	29.7	74.3	•793	876	
22	15	5.13	34.9	70.2	.833	707	
23	11	3.76	38.6	65.0		539	***
24	18	6.16	44.8	61.3	.912	370	- \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
25	14	4.79	49.6	55.1	•952	202	
26	18	6.16	55.8	50.3 44.1		034	
. 27	13	4.45	60.2	44 • 1 39 • 7	1.031	•134	
28	23	7.87	68.1	39.7	1.071	.302	
29	. 11	3.76	71.9	25.0	1+111	.471	1
30	16	5.47	77.3	23 • 0	1.150	•639	
31	14	4,79	82.1	17.8	1.190	-808	•
35	ß	2.73	84.9	15.0	1.230	•976	
. 33	15	5.13	90.0	9.9	1.269 1.309	1+144	
34	50	6.84	96.9	3.0	1.309	1.313	
35	9	3.08	100.0		1.388	1.481	
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STANDARD DEVIATION

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## OPS MODEL STUDY

# APPENDIX D

## CRITIQUE OF NASA'S MODELING OPERATION

REPORT NO. SU-OPS-RP-73-0002D

PREPARED FOR THE

GEORGE C. MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA

CONTRACT NUMBER

NAS 8-30302

PREPARED BY

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., N. Y.

DATE: 7 November 1973

#### APPENDIX D

#### 1.0 STUDY TASK

In this task a critique was performed on the NASA modeling operation.

#### 2.0 INTRODUCTION

A sample GPSS-III Simulation Modes, developed by NASA, was reviewed by GAC as to programming technique and depth of analysis. This particular model was a somewhat outdated version of the "Sortie Lab-Ship and Shoot".

### 3.0 DISCUSSION

The first part of the simulation is involved with the determination of mission hardware requirements. This process involves a random pick to determine which particular flight, out of a total of 33, is going to be launched. Once the flight is determined various equipment and payloads are chosen in accordance with the particular flight.

This random scheduling routine seems to work quite well; however, it might be more involved than is actually necessary. A predetermined launch schedule, based on payload requirements, would involve considerably less programming and could prove to be more flexible. Since in actual practice the launch schedule will be well thought out and planned in advance, a predetermined schedule seems to be a more realistic approach.

The second part of the simulation represents the actual flow of equipment through the ground operating system. This flow is relatively straight forward, and to a great extent, follows the "English Language" diagram. This routine, however, could be expanded to show more detail in various operations; such as, Inspection, Safing, Integration, etc. Major pieces of equipment and facilities involved with these operations should also be included in the model. This will permit greater visibility into the actual equipment requirements, and the relationship between the equipment and the performance of the total payload ground operations system.

### APPENDIX D

# 4.0 COURSE OF ACTION

Grumman will continue to review NASA's simulation models as to programming technique and depth of analysis. Once a Sortie Lab baseline is established and a simulation modeling effort begins, Grumman will review the model and make recommendations in order to increase the effectiveness of the model.